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ISSUED SEPTEMBER 11TH, 1897.

VOL. XX.] [No. 5.

PROCEEDINGS

OF

THE SOUTH WALES INSTITUTE OF ENGINEERS.

[EMBRACING THE COAL-FIELDS OF SOUTH WALES
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5th *July*, 1897.

EDITED BY THE SECRETARY.

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1857

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NOTICES.

The Editor of these Proceedings is directed to make it known that the Authors alone are responsible for the facts and opinions contained in their respective Papers, and the individual Speakers for their Statements made in Discussion.

All communications to be addressed to the Secretary, Mr. Hort. Huxham, Swansea; from whom back Numbers of Proceedings may be had, and also printed Forms of Application for Admission of Candidates as Members.

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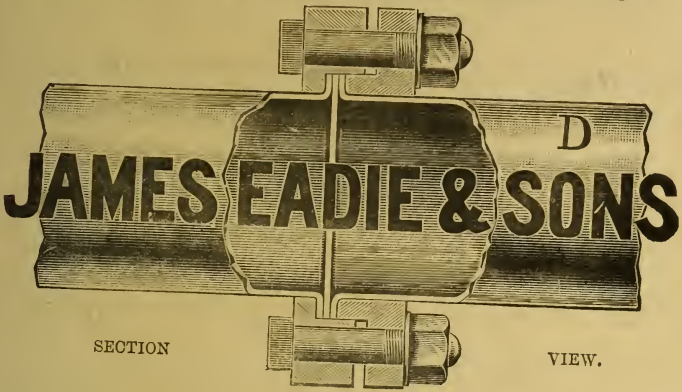

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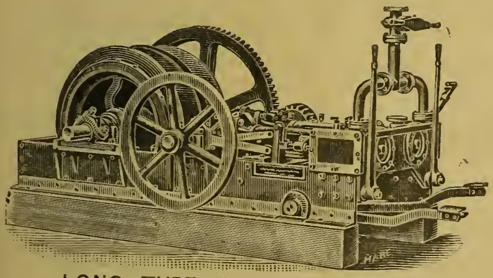

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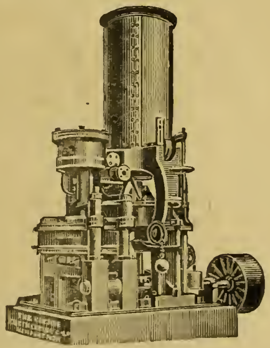

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PROCEEDINGS.

5th July, 1897.

The General Meeting of the Institute was held at the Lecture Theatre of the Institute, Park Place, Cardiff, on Monday, the 5th July, 1897.

Mr. HENRY W. MARTIN, M.Inst. C.E., President, in the chair.

The Minutes of the last General Meeting were read and confirmed.

ELECTION OF NEW MEMBERS.

The President announced that the Ballot Lists had been opened by the Scrutineers, and declared the following gentlemen duly elected to the Institute, viz.:—

As Members.

Baker, J. E.	Cardiff.
Bounsall, Tyeth D.	London.
Davies, Edward Herbert	Newport.
Richards, Evan S.	Cardiff.
Thomas, Richard	Penarth.
Thomas, Iltid Edward	Swansea.
Walker, Henry Blair	Johannesburg.

As Associates.

Burnell, J. E.	Llanelly.
Lewis, W. Yorath	London.

ADMISSION OF NEW MEMBERS.

The following gentlemen were admitted to the Institute, and signed the Roll-book, viz. :—

Baker, J. E.	Cardiff.
Bounsall, Tyeth D.	London.

Adjourned Discussion on "The Transvaal Coalfield."

The President. The President said the first matter on the agenda was to resume the discussion of Mr. W. Forster Brown's Paper on "The Transvaal Coalfield."

Mr. T. H. Bailey. Mr. T. H. Bailey said he thought it might possibly be of interest to the members of the Institute if he gave some particulars of a visit to the Transvaal by a member of his firm in the year 1889, so that they might compare the information which had been given by Mr. W. Forster Brown with that which his firm obtained when they inspected the district at that time. In that year they visited that part of the Transvaal Republic which was reputed to contain the best coal seams, in order to discover the locality of the richest iron ore, and a supply of limestone, suitable for the establishment of ironworks; regard being had to all the necessary requirements, not only for the production of iron at the cheapest rate, but also as centrally situated as possible for the supply of the various markets of the Republic and the neighbouring States. The Transvaal Republic, as had been explained by Mr. Forster Brown, was situated about 700 miles north of Cape Town, between the 22nd and 27th degrees of south latitude, and the 25th and 32nd degrees of east longitude. Its eastern boundary was Portuguese territory, and distant about 40 miles from Delagoa Bay; its northern boundary was the Limpopo, or Crocodile River; its western boundary Bechuanaland; and its southern boundary the Vaal River. It comprised an area of over 120,000 square miles, and was somewhat larger than Great Britain and Ireland put together. The central part, the Hooge Veldt, a high plateau, formed the principal watershed of the Republic. The climate was healthy, and the soil productive. The country was well watered, and it was exceedingly rich in almost every mineral. The west and north of the territory was, geologically speaking, composed of immense deposits of slates and conglomerates, traversed by great diorite dykes, which here and there appeared to have overflowed and capped the "kops" and mountains, and the edges of the beds of sedimentary rocks, which were upturned at all angles. Some upturned conglomerate beds in these slates were the gold-yielding and so-called "banket" reefs of Johannesburg and elsewhere. The coal measures appeared to be deposited unconformably on these slates, but to be of more ancient origin than the diorite dykes and overflows, which had pierced through the coal measures at greater or less intervals over the whole coalfield. They inspected the Wall Drift coal on the Klip River, lying about 30 miles south of Johannesburg, the seam being from 5 ft. 6 in. to 6 ft. 6 in. thick. It had many alternations of bright coal, hard dull bands, and shale partings, and was very irregular in bedding, so that no two sections of the seam would quite correspond. The following was an average section of the seam:— **Mr. T. H. Bailey.**

SECTION OF WALL DRIFT COAL.

	ft.	in.
Dicey Coal	0	3
Bright Hard Coal	0	10
Bat and Coal	0	5
Streaked Hard Coal	2	6
Hard Dull Coal	0	5
Bright Hard Coal	0	5
Hard Dull Coal	1	0
Total . . .	5	10

Floor of Hard Shaley Bind and Fireclay.

Mr. T. H. Bailey.

The best portion of this seam contained, by analysis, combustible matter 80·8 per cent., ash 19·2 per cent. A large fire of this coal, made in the open air, with a strong breeze blowing, gave the result of a very unsatisfactory fire as regards heat; gave very little flame, and left almost as large a bulk of grey ash (the shaly part retaining its original shape) as when the fire was lighted. Such a seam was quite unfit for use in a blast furnace. Further than this, the Wall Drift coal-field was intersected with numerous diorite dykes at such frequent intervals that the area of coal seams between them would be of limited extent, and in a disturbed condition.

On an estate belonging to Messrs. Lewis & Marks, of 40,000 acres on the Vaal River, in the south of the Transvaal, the coal seam, to which a shaft had been sunk, was 36 yards from the surface. It was 8 ft. thick, without bands or divisions, and of nearly uniform quality, equal to the best parts of the Wall Drift seam. On this farm there existed a large extent of impure limestone, called cement stone, which contained about 28 per cent. of iron, silica, alumina, &c., and about 70 per cent. of carbonate of lime. In this district iron ore appeared to be abundant, which from samples obtained was estimated to contain from 30 to 60 per cent. of metallic iron. It appeared in nearly vertical reefs, from 6 ft. to 12 ft. wide, near the diorite dykes before mentioned, which ran east and west, and occurred all the way between this locality and the north of Pretoria.

Of the coals brought into the Johannesburg market, the "Steen Coal Spruit," "Wilge River," and "Koorn Spruit" coals were of best repute, selling at the time for 15*s.* per bag of 200 lbs. weight, or £8. 5*s.* per ton, delivered at Johannesburg.

The Wilge River workings lay due east, at a point equidistant from Pretoria and Johannesburg, and about thirty miles therefrom. One belonged to the Anglo-African Coal Company, and the other to Holfontein Companies. The following was a section of the Holfontein Mine:— **Mr. T. H. Bailey.**

SECTION OF COAL AT HOLFONTEIN MINES.

	ft.	in.
Bright Coal	0	6
Hard Coal	0	8
Bright Coal (A)	4	4
Hard Coal (B)	1	8
Bright Coal (C)	3	8
Total	10	10

Two samples of this seam gave the following analysis:— (A) combustible matter 68·8 per cent., ash 31·2 per cent.; (C) combustible matter 90·7 per cent., ash 9·3 per cent. A large fire made of the bottom coal gave a good heat (bright cherry, approaching white), nearly equal to a good English house-coal. This immediate coalfield was undisturbed, and the seams lay flat and regular.

At a mine at Boksburg, lying direct east of Johannesburg, and about fourteen miles therefrom, the coal was of inferior quality and not worthy of notice. It was selling at 5*s.* a bag of 200 lbs., or £2. 15*s.* per ton delivered at Johannesburg.

At the Brakpan Mine the quality of the coal was very little better.

There was a mine belonging to Mr. White, about seven miles south of Middleburg, which was shown on Mr. W. Forster Brown's map. The seam of coal was 8 ft. thick. The combustible matter was 87 per cent., and the ash 13 per cent. It was a very hard steam-coal, similar to that of the Northumberland coalfield, but containing more ash.

Then there was the Robinson's Mine, near Vaal Kop, where a seam of coal of the following section was opened by an adit:—

Mr. T. H. Bailey.

SECTION OF COAL AT ROBINSON'S MINE.

	Coal	Bands
	ft. in.	ft. in.
Coal	0 10	—
Band	—	0 7
Coal	0 11	—
Band	—	0 3
Coal	0 11	—
Band (Sand)	—	0 1½
Coal	0 6	—
Band (Sand)	—	0 2
Coal	0 2	—
Band	—	0 1
Coal	0 5	—
Band	—	0 1
Coal	1 4	—
Band	—	0 1
Coal	0 5	—
Band (Pyrites)	—	0 1
Coal (Bright Hard)	1 1	—
Total	6 7	1 5½

An analysis of this coal gave combustible matter 84·1 per cent., and ash 15·9 per cent.

Immediately north of Robinson's Mine was that of the Randt Coal Company, situated at the junction of the Koorn Spruit and the Olifants River, and five miles south of the junction of Steen Kool Spruit with that river. Here there was a remarkable open working of coal from 10 ft. to 12 ft. thick, very nearly free from slaty bands, and of good quality. From information it was learned that the price at the mine was 14*s*. a ton, and the selling price at Johannesburg varied, according to the cost of transport, up to £8. 5*s*. a ton. The average cost of working was about 6*s*. per ton, including capital and other charges. An analysis of the top part of the seam was as follows: Combustible matter 94 per cent., ash 6 per cent. The middle part: Combustible matter 92·7

Mr. T. H. Bailey.

per cent., ash 7·3 per cent. The bottom part: Combustible matter 91·4 per cent., ash 8·6 per cent.

There were four farms about fifteen miles S.S.E. of Middleburg, containing an area which was considered the best coal in the district—Pullen's Hope, Seven Fountains, Optimus, and Bushman's Kop. The coal was cropping out in several instances along the hill sides, and also the coal measure sandstone. There were three trials for coal at that time on Pullen's Hope. The one to the south had not reached the coal, the middle one was just on the top of it—two feet was to be seen—and there was one to the north in a cutting 8 ft. wide exposing the coal.

Section of Pullen's Hope Coal, South of Middleburg.

	Coal	Shale
	ft. in.	ft. in.
Coal (Bright)	0 6	—
Shale	—	0 6
A.—Coal	1 0½	—
Shale	—	0 6
B.—Coal (Bright)	1 0	—
Coal (Hard)	0 2½	—
Coal (Bright)	0 4	—
Coal (Hard)	0 8	—
Coal (Bright and Strong)	1 6	—
C.—Coal (said to be)	2 4	—
Total	7 7	1 0

The analysis showed the following results:—

	A.	*B.*	*C.*
Sulphur . . .	1·66	1·79	·87
Moisture . . .	3·63	4·43	4·01
Ash	7·83	7·37	10·14
Carbon . . .	67·00	62·00	66·50
Volatile Matter . .	19·88	24·41	18·48

This seam appeared to have a very extensive range.

Mr. T. H. Bailey.

On the same farm there was a deposit of magnetite, containing by analysis 66·23 per cent. of metallic iron. Further east on the farm was a seam of hematite lying very level, and apparently a sedimentary deposit consisting of hard bed, 1 ft. 8 in., 63·38 per cent. of iron; softer, 1 ft. 6 in., 53·24 per cent. with a trace of phosphoric acid; and a hard bed, 1 ft. 8 in., 64·07 per cent. of iron. The total thickness was 4 ft. 10 in. At a further distance eastward about half a mile on the same farm was an outcrop of magnetite similar to that above mentioned. Over all these farms were surface deposits of pisolitic ore, locally called "Old Klip." This varied very much in quality, and contained from 20 to 40 per cent. of metallic iron. An analysis of a sample from Pullen's Hope showed 39·82 per cent. of metallic iron. On these farms there was a small digging near the outcrop, and there a fireclay was exposed, which gradually in depth became more silicious and less plastic, and judging from its appearance it was highly silicious and therefore fire-resisting. There was also on the same farms an abundant supply of building-stone and clay, suitable for common bricks, tiles and quarries, which could be utilised in the erection of works and houses.

At Bush Veldt, some forty or fifty miles north of Middleburg, and within a radius of about ten miles from Maleo's Kop, there was an inexhaustible supply of good limestone, which would be most valuable for ironworks. Limestone pebbles were also found over these farms.

In the district of the Rivers Olifants and Little Olifants the high veldt was of an undulating character, with wide swelling downs and valleys, and spruits or brooks falling into the rivers.

The water supply was a matter of great importance in a country where they had to set up ironworks or collieries, and especially where there were long droughts, like there

Mr. T. H. Bailey.

were in South Africa. The Middleburg district was one of the best watered in the Republic. An adequate supply might be secured in the immediate neighbourhood of the proposed works, either by dams thrown across the valleys in a line with the diorite dykes; by pumping from shafts sunk near thereto, should the reservoirs prove insufficient; or from the Little Olifants River, where there was water all the year round.

There was a great scarcity of timber in all the coal districts visited, but he believed timber grew very rapidly, especially in the well watered valleys, requiring for the first year or two attention as to watering in times of drought. The planting of blue gums, golden willows—locally known as black whattle—and acacias would amply repay any owner or company engaged in the coal and iron trades. Suitable timber could be cut from such plantations for mining purposes, which would probably be after five or six years of planting, but all building timber had to be imported.

He would conclude his remarks by referring to a paragraph which appeared in the *Western Mail* that morning with regard to the question of the quality of the coal in the Middleburg district, in which the writer said it would probably come into competition with South Wales coal. He gave an analysis which was taken apparently from the *Standard and Diggers' News*. The figures given were as follows:—"South Wales Coal: Carbon, 90·39; hydrogen, 3·28; oxygen, 2·98; nitrogen, 0·83; sulphur, 0·91; ash, 1·61; specific gravity, 1·392. Middleburg Deep: Carbon, 89·24; hydrogen, 3·02; oxygen, 2·84; nitrogen, 1·10; sulphur, 0·79; ash, 3·01; specific gravity, 1·429. From the above analysis it would appear that the Middleburg Deep seam would in the near future be able to compete with South Wales coal in over-sea markets, and supply three-quarters of the coal requirements of the southern hemisphere."

Mr. Hort. Huxham.

Mr. Hort. Huxham[1] said, in considering Mr. W. Forster Brown's Paper on the Transvaal Coalfield, it might with profit, he thought, be taken in conjunction with Professor W. Galloway's Paper on the South African Coalfield, read before the Institute in November, 1890, seeing that Mr. Brown's Paper formed a very interesting addition to the general knowledge of that huge coal-bearing area, and gave valuable particulars and details relating to its northern portion which tended materially to modify the views that might be entertained from a consideration of the particulars relating to the southern portion, as set forth in Professor Galloway's Paper, with regard to the quantity and quality of the coal likely to be met with in the South African Coalfield. In the south, in the neighbourhood of Molteno and Indwe, Professor Galloway stated that only one workable seam of coal had yet been found, much divided into thin beds by bands of shale and stone.

Thus, the seam at the following places, comprised:

		Coal.			Shale.		Total.	
		ft.	in.		ft.	in.	ft.	in.
Molteno . .	3 beds of coal	2	6,	and 2 bands	1	4	3	10
Fairview . . .	4 ,,	2	2½,	,, 3 ,,	1	10	3	0½
Carnarvon . .	3 ,,	3	1,	,, 3 ,,	1	3	4	4
Umkapusie . .	4 ,,	4	1,	,, 4 ,,	2	3	6	4
Doornkopje . .	6 ,,	3	9,	,, 4 ,,	5	2	8	11
Indwe	5 ,,	3	8,	,, 4 ,,	3	2	6	10

And in those localities the presence of dolerite, or intrusive igneous rock, had had the effect of driving all the volatile matter out of the coal, leaving only a dull grey lustreless anthracite, which did not burn with that vivacity desirable for industrial and household uses.[2] Whereas in the northern

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[1] Time being somewhat limited for the discussion of the many interesting issues involved in Mr. Brown's paper, Mr. Huxham felt obliged to very much curtail his observations and omit quotations and references to other writers on the subject. Believing that the geological features are of peculiar interest, he has ventured to revise his remarks from his notes and add the quotations and other matter to which he referred.

[2] "Proceedings South Wales Institute of Engineers," No. 2, Vol. xvii., pp. 76–78.

Mr. Hort. Huxham.

portion, as described by Mr. W. Forster Brown, there appeared to be in the neighbourhood of Boksburg two distinct seams, giving a thickness of from 20 ft. to 78 ft. of coal; and that in the neighbourhood of Carolina and Ermelo there were some twelve seams with a thickness of 50 ft. of coal, of which, four seams with an average thickness of 17 ft. of coal were of sufficiently good quality to be worked at the present time. It appeared also that although the intrusion of igneous rock (dolerite) in the form of dykes had been frequent and persistent in character over long distances, it had not materially affected the seams of coal, except in a few instances, where the coal had been burnt in the immediate vicinity of the dykes.

In the *Colliery Guardian* of June 25, there was an interesting paragraph relating to the proving of a thick seam of coal to the south of Heidelburg, between the Upper and Lower Rooi Kopjes. A borehole was put down at Beerlaagte, when it encountered and passed through a sheet of dolerite 310 ft. in thickness, and at 550 ft. met a seam of coal 25 ft. thick, which, according to Mr. Sawyer, the owner of the property, was the first time coal had been found by boring or sinking underneath dolerite in the Transvaal. Another borehole was put down six miles away, at Grootvlei, when the dolerite was struck at a depth of 118 ft., and proved only 25 ft. in thickness. The coal seam was intersected at 468 ft., and proved to be 60 ft. in thickness, of good quality, containing but little sulphur, and with hardly any bands in it. A shaft 11 ft. in diameter was here started in September, 1896, and the coal was reached at a depth of 510 ft. on June 8, 1897, and the colliery, to be called the South Rand Colliery, was now being opened.

In Papers on the Natal Coalfield, by Mr. J. P. Hamilton[1] and Mr. R. A. S. Redmayne,[2] contributed to the Federated

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[1] "Transactions Federated Institution of Mining Engineers," Vol. 3, p. 874.

[2] *Ibid.*, Vol. 4, p. 553.

Mr. Hort. Huxham. Institute of Engineers, the writers gave sections of several seams of workable coal, of very variable thicknesses, but of good quality, especially for steam purposes. The Natal portion of the South African Coalfield occupied a position on the eastern side, about half way between the extreme northern and southern limits, so that it might be assumed that workable coal seams extended over a very much larger area, and were likely to bear a very much more important commercial aspect in the future, than one would have been justified in assuming from the particulars given of the southern portion of the coalfield in Professor Galloway's Paper.

Before discussing some of the geological features of the country, he desired to call attention to a typographical error at the seventh line from the bottom of page 136 of Mr. Brown's Paper, where the semicolon after "Recent deposits" should have been a comma.

The general geological features of South Africa appear to have been pretty well ascertained, but as the country was so extensive, and had only in its greater part been explored in comparatively recent years, there was a very great deal of geological work to be done in recording and tabulating the details of local areas. There had been a great many excellent workers in the field, but, so far as he had been able to ascertain, the late Professor Green appears to have given the most concise general classification of the strata and record of the chief geological features.[1]

The table given on pp. 266–267 exhibits the classification adopted by Professor Green, compared with that of the author (Mr. W. Foster Brown), Mr. R. Tate, Professor W. Galloway, Mr. J. P. Hamilton (Natal), and Mr. R. A. S. Redmayne (Natal).

It was particularly to be noticed that Professor Green drew

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[1] "Quart. Journ. Geol. Soc.," Vol. 44, p. 239

Mr. Hort. Huxham.

attention to the unconformity which existed, first, between the "Basement Rocks" and Table Mountain Sandstone; then between the Quartzites and the Dwyka Conglomerate; and last, and especially, between the Ecca Beds and Kimberley Shales and overlying strata.

This unconformity, which was of special geological import, seems to have been either overlooked or not dwelt upon by most of the other writers. He need hardly say that each marked unconformity of stratification indicated the intervention of an immense period of geological time during which earth movements and subsequent denudation set in, before the deposition of the next succeeding strata commenced.

There were many extremely interesting features in connection with the coalfield from a geological point of view.

The nearly horizontal and but little disturbed condition of the strata by faults or contortions from the bottom of the Kimberley Shales upwards, spoken to by all writers, was a very noticeable feature over so extensive an area, and, so far as he knew, unique in the characteristics of any known coalfield. The enormous outflow of volcanic rock, or dolerite, which subsequent to the deposition of the Cave sandstone became spread over a large portion of the area, and had also forced its way horizontally between the stratified beds, and in places formed huge dykes extending for considerable distances, was also a very marked feature of the coalfield, and it was wonderful to find how little the strata had been disturbed, and how little damage had been done to the coal seams, considering the extent and violence of that eruption. At the same time, there could hardly be any doubt that it had formed an almost impervious mantle, protecting the coalfield to a great extent from denudation.

It was difficult to conceive the forces of denudation which had brought about the physical conditions so well

TABLE. CLASSIFICATION OF SOUTH AFRICAN STRATA.

Professor A. H. Green, 1888*				Mr. W. Forster Brown, 1896†	Mr. Ralph Tate, 1867‡		Prof. W. Galloway, 1889§	Mr. J. P. Hamilton, 1892 (Natal Coal Field)‖	Mr. R. A. S. Redmayne, 1893 (Natal Coal Field)¶
	Tertiary Cretaceous Oolitic, or Jurassic		Scraps of, lying close to the coast, and apparently formed at no great distance from the shore.	Recent Deposits.	— —		— —	— —	Alluvial. Cretaceous, Chalk on S.W. coast line.
Stormberg Beds	Volcanic Beds		Intrusive trap. Rudely columnar dolerite.	Volcanic Rocks.	Stormberg Beds.	Triassic.	Volcanic Beds.	Basaltic Trap Rocks.	Igneous Rocks and Outflows, capping the mountain ranges.
	Cave Sandstones	Strata more or less horizontal, or with very slight inclination.	Finely-grained light-coloured massive sandstone, which weathers white, forming magnificent escarpments along the hill sides; base largely undermined by the weather into rock shelters or caves.	Cave Sandstone.			Cave Sandstone (300 ft.).	Triassic Beds with Coal Seams, corresponding with the Stormberg Beds.	Coal Measures, Triassic (about 4,000 ft.).
	Red Beds		Red thick beds of shale, with thin beds of sandstone, containing reptilian remains.	Red Beds.			Red Beds (1,500 ft.).		
	Molteno Beds		Massive beds of fine and coarse grey quartzose grits and conglomerates, forming lofty, precipitous, and rugged "Kranzes," alternating with thin beds of grey and dark-coloured shales, and beds of coal.	Molteno Beds, or Coal Measures.			Molteno Beds (coal measures) (1,000 ft.).		
Karoo Beds			Thin beds of finely-grained soft sandstones, weathering pale buff colour, with occasional beds of harder and more quartzose grits, alternating with thick beds of red and greenish shales. Fossils include reptilian bones, fresh-water shells, and plant remains (*Glossopteris*, *Dictyopteris*, &c.), pointing to the conclusion of this being a fresh-water deposit.	Karoo.	Beaufort Beds.		Karoo Beds (5,000 ft.).		
Kimberley Shales			Grey and dark sandy shales, and mudstones, with occasional thin beds of sandstones and thin layers of argillaceous limestone. Fossil plants are found, and occasionally small thin lenticular beds or nests of coal. These strata rest unconformably on the Ecca Beds.	Kimberley Beds.	Koonap Beds.		—	Pietermaritzberg Shales.	Pietermaritzberg Shales (Middle Trias).

Ecca Beds (4,000 ft.) . . .	Consist largely of hardened sandy clays, or mudstones, without lamination; and numerous beds of finely-grained, highly quartzose sandstone, with spheroidal weathering. These beds lie conformably on the Dwyka conglomerate, and have been bent into a number of folds with axes ranging east and west; practically no fossils have been found.	Ecca Beds.	Ecca Beds.	—	—	—
Dwyka Conglomerate . . .	A very remarkable mass of breccia and conglomerate of variable character, but very coarse in places. Consisting usually of a matrix of greenish dark opaque substance, set with transparent fragments of all sizes and shapes, chiefly angular, and most unmistakably chips of limpid quartz; in the matrix are set larger fragments and boulders, chiefly of quartz and quartzite. These beds are, with the Ecca beds, bent into a number of folds.	Dwyka Conglomerate.	—	—	Conglomerate, or Boulder Clay.	**Boulder Clay.**
	Unconformity.					
Quartzites of Zwerbergen . Zwartebergen . Wittebergen .	Beds of massive white quartzite, with bands of more thinly-bedded quartzite and shale. Very much folded and contorted. Generally barren of fossils, but some traces of *Lepidodendron*, *Sigillaria*, and other Carboniferous plants, have been found, and thin streaks of anthracite coal.	Cape Formation.	—	—	—	—
Bokkeveldt Beds	Consist of thick beds of slates and sandstones, much folded and contorted. The fossils that have been found are analogous with the Devonian of Europe.		—	—	—	—
Table Mountain Sandstone .	Generally coarse, massive grits.		—	—	Sandstones, probably Silurian.	Silurian (500 ft.).
	Great unconformity.					
" Basement Rocks" (Malmsbury Beds) . . .	Are largely crystalline in character, and consist mainly of clay-slate, with intrusive masses of granite.	Primary Formation.	—	—	Primary Rocks.	Pre-Silurian.

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* Quart. Journ. Geol. Soc., Vol. 44, p. 239 *et seq.* † Proceedings of the S. Wales Inst. of Engineers, Vol. xx., p. 137. ‡ Quart. Journ. Geol. Soc., Vol. 23, p. 167. § Proceedings of the S. Wales Inst. of Engineers, Vol. xvii., p. 71. ‖ Trans. of the Federated Inst. of Mining Engineers, Vol. 3, p. 874. ¶ Trans. of the Federated Inst. of Mining Engineers, Vol. 4, p, 553.

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described in Professor Galloway's Paper.[1] First, in breaking through and removing large areas of the adamant basaltic rocks, 50 to 100 feet or more in thickness, which spread like a covering mantle over the coalfield; then eroding and removing from the larger portion of those areas left unprotected by the basaltic covering, some 300 feet in thickness of the Cave sandstone; and then 1,500 feet of Red Shale beds and sandstones lying below; exposing the hard, gritty sandstone and conglomerates of the Molteno beds, or coal measures proper—some 1,000 feet in thickness—whilst those in turn had been cut through and denuded, leaving precipitous escarpments (or Krantzes) in huge steps from 20 feet to 100 feet in height, strewn with great blocks of rock that had last fallen along the slope at the foot of each Krantz, and in some places the rivers had cut through the 1,000 feet and made their beds in Karoo formation below; whilst still further away, all round the coalfield, the Karoo beds and large portions of the Kimberley Shales had been removed. Had the strata from the Kimberley Shales upwards been folded into huge synclinals, and subjected to marine denudation, and afterwards elevated and exposed to the action of sub-aerial denudation, it would be comparatively easy to account for the removal of such enormous masses of strata; but in the case in question, although the country generally might have been, and no doubt was, subject to gradual depression during the deposition of the Kimberley, Karoo, and overlying beds, and to subsequent gradual elevation, there was no evidence of any material contortion or folding of the strata subsequent to the age of the Ecca beds; and whilst the extent of the original deposition of the superior strata was at present quite unknown, it was evident from its present horizontal position and denuded escarpments that it must have occupied an immensely greater

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[1] "Proceedings of the South Wales Institute of Engineers," Vol. xvii., pp. 72–75.

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area than could now be observed, and he thought that the only possible way to account for its present physical condition was to suppose that it went under a process of very gradual elevation, and during that period was insular in form, and exposed to marine denudation and glacial action, by which large areas of each succeeding strata were broken off and swept away, leaving great precipices on the sea-front, the land afterwards being subjected to the minor action of sub-aerial denudation.

In a Paper read before the Geological Society in 1870, the late Mr. G. W. Stow attributed the denudation chiefly to glacial action. He says[1]:

> The encroachment and retreat of the sea cannot have effected the vast denudation either during the subsidence or upheaval of the land, for there is no evidence that any of the strata, except those on the immediate coast, have been subject to oceanic action. The denudation, he thought, had been chiefly effected by glacial action, under an antarctic climate. Moutonnées and mouraines were abundant, and large masses of breccia embedded in clay were also numerous.

It was interesting to notice that Professor Green pointed out that the Zwartebergen, Wittebergen, and some other hill ranges had all the distinctive character of true mountain ranges, composed chiefly of elevated and folded beds of quartzites; whilst the Camdebog, Nieuwveldt, Stormbergen, and the great Drakenberg ranges were all hills which had been carved out by denudation from the horizontal strata of the Kimberley Shales and overlying beds, and had no right to the title of mountain ranges in the geological sense of the term, although varying in height from 7,000 to 10,000 feet above sea-level, and were physically of a very wild and rugged character. Their summits stood from 3,000 to 4,000 feet above the plains to the north and south, and were monuments of what the forces of denudation could do, and of the enormous lapse of time necessary for their formation.

[1] "Quart. Journ. Geol. Soc.," Vol. 27, p. 538.

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He could not altogether agree with the remarks of Mr. Jas. McMurtrie on p. 221, in comparing the broader geological features of South Africa with those of this country. It was true there were somewhat analogous "Basement Rocks," consisting of granites and primary crystalline schists, and rocks of sedimentary origin, above which lying unconformably were beds of sandstones said to be of Silurian age. Then came thick beds of slates and sandstones (Bokkeveldt Beds) with paleozoic fossils analogous to the Devonian of Europe; and again above those, beds of quartzites and shales, in which fossils of *Lepidodendron*, *Sigillaria*, and other carboniferous plants had been found, and also thin layers of anthracite coal; and so far a broad analogy might be set up. But it appeared to him that the comparison could not be carried further, for unconformity again became apparent between the last mentioned beds and the overlying Dwyka Conglomerate and Ecca Beds, in which there were said to be hardly any traces of fossils.

A long period of earth movements then ensued, by which the strata were much folded and contorted, and subsequent denudation set in, but to what extent it was impossible with the present knowledge to conjecture.

Thereafter, an entirely new geological epoch succeeded, during which the Kimberley Shales and the enormous thickness of overlying beds were laid down horizontally over the upturned floor of the preceding strata, which had been more or less planed away by denudation. These beds, which still lay horizontally, showed very slight indications of having been disturbed since they were deposited, except by an extensive outflow of dolerite and a very gradual elevation and severe denudation.

The fossil remains were stated to be of mesozoic character, and appeared to indicate that the strata were probably of Triassic age, rather than analogous to the true Carboniferous period.

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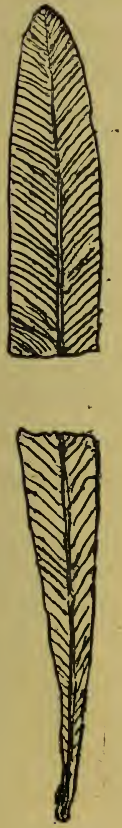
Reptilian remains from the Karoo beds of the Stormberg mountains, about thirty miles north of the town of Aliwal, were sent to Professor Huxley in 1866, and in a communication to the Geological Society[1] in that year, he stated that it was a Dinosaurian reptile, which he named "*Euskelesaurus*." He added:

> The occurrence of Dinosaurian remains in the Stormberg rocks is unfortunately by no means decisive of the geological relations. The Dinosaurian *Plateosaurus* has been discovered by Von Meyer in the Trias; and the affinities of the Theodants and the Dinosauria are so close, that no one could be surprised at the occurrence of the latter reptiles in rocks of the Permian age; while on the other hand they are continued through the mesozoic formations to the chalk.



Glossopteris Browniana.

In a communication to the Geological Society in 1867, Mr. Ralph Tate says[2]:

> The flora of the Karoo beds presents close analogy with that of the coal formation of Eastern Australia, and plant-bearing beds of Burdwan and Nagpur in India. The characteristic plant in each of those deposits and in the Karoo beds is a *Glossopteris*, and it seems that the Indian, Australian, and South African plants are specifically identical. The flora of the Karoo beds cannot be regarded as contemporaneous with the Jurassic flora of Europe, but as it possesses a mesozoic facies, it may be considered to be of Triassic age. The nature of the flora conspires with the fauna to establish the lacustrine origin of the Karoo series.

In a Paper read before the Geological Society in 1870, Mr. G. W. Stow says[3]:

> The Karoo beds were probably a fresh-water deposit—that is, lacustrine, either of one or many lakes or successive lakes.
>
> Large quantities of fossil wood are found in some of the latest sand-stones of the Stormberg formation. In some places there are trunks of trees (Coniferæ), 20 to 30 feet long and great number of segments,

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[1] "Quart. Journ. Geol. Soc.," Vol. 23—Nov. 1866.

[2] *Ibid.*, Vol. 23, p. 142.

[3] *Ibid.*, Vol. 27, p. 497.

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which stand erect in the position in which they grew; these latter were often 8 to 9 feet in circumference.

In a Paper on the Geology of Natal by Mr. C. L. Griesbach, read before the Geological Society in 1870, the author says[1]:

> Numerous remains of reptiles and plants are described which came from the Natal side of the Drakenberg, and therefore the age of those beds may be determined. Mr. Tate regards them as Triassic, whilst Mr. Wyley thinks they belong to the Carboniferous period; but as the coal from Tulbagh in the Cape Colony (to which Mr. Wyley refers) is decidedly Carboniferous (*Calamites*, *Equisetum* and *Lepidodendra* in the sandstone), and as the succeeding Karoo formation, which is a fresh-water deposit, does not lie conformably on the former, Mr. Tate's opinion seems the most acceptable. Also the same formation with *Dicynodon* and *Glossopteris*, occurring in India at the base of the Cretaceous series, is proved, by a careful examination of its flora, to be a Triassic deposit. There can certainly not be the slightest doubt that the Natal coal belongs to a far younger period than the Tulbagh coal, which is equivalent to our coal measures. Probably Africa and India were originally connected by a cretaceous sea.

In a Paper by Mr. Redmayne on the Geology of Natal in 1893, he says[2]:

> The most characteristic fossil of the few found in the coal measures (Molteno Beds) is *Glossopteris*, which is eminently a Triassic fossil. No remains of *Stigmaria* or *Sigillaria* have as yet been discovered, and the writer has only seen one specimen of *Lepidodendron*, found near Newcastle.

Another point of very great geological interest referred to in the author's Paper, and also raised in Professor Galloway's Paper and by other writers, was the question of the origin and mode of deposition of the coal seams of South Africa. The author, in referring to the matter on page 173, had quoted observations made by Professor Galloway in a paper read by him before the Cardiff Naturalists' Society in 1885; and as that paper set forth shortly and succinctly the opinions of the

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[1] "Quart. Journ. Geol. Soc.," Vol. 27, p. 57.

[2] "Federated Institution of Mining Engineers," Vol. 4, p. 553.

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adherents of two hypotheses on this great question, it would be well to quote an abstract of that portion.[1]

> All geologists are agreed that coal is of vegetable origin, but they are by no means unanimous as to how the vegetable matter came to occupy its present position.
>
> There are two principal hypotheses, each of which has its adherents, and each of which I shall endeavour to describe as shortly as possible. The dense and homogeneous nature of coal prevents anything like a definite opinion being formed as to the exact nature of the plants of which it is composed; and perhaps one hypothesis may be correct as regards some localities, and the other as regards other localities.
>
> The fossils found in the clay beds underneath the coal are mostly *Stigmaria*, whilst the fossils found in the shales and sandstones are principally *Lepidodendron*, *Sigillaria*, and *Calamites*.
>
> The beds of clay in which *Stigmaria* are found usually underlie the seams of coal, and hence are called " underclay." It is remarkable that few seams of coal are found in this country, or other parts of the world, without its accompanying bed of underclay and its fossil *Stigmaria*. This circumstance led some geologists—amongst whom Sir W. Logan was, I believe, the first—to suppose that the underclay constituted the actual soil upon which the coal plants grew, and that *Stigmaria* is the root, or rhizome, of the *Lepidodendron* and *Sigillaria*. The conclusion seems natural, and yet it is surrounded with difficulties of no ordinary kind.
>
> De Luc, in 1793, was the first to promulgate the theory that the coal plants grew, died, and decayed on the spot where we now find them. His views would appear to receive very substantial support from the facts regarding the underclay and its stigmarian remains.
>
> Supposing his theory to be correct, we have next to inquire what the surrounding circumstances must have been at the time. As a first condition it is requisite to have a nearly level plain at, or slightly under, the level of fresh water, sometimes undergoing depression and sometimes upheaval, and liable to be inundated by the waters of a great river. Supposing the plain had previously formed the site of an inland sea which became silted up by the deposition of the mountain limestone and the millstone grit, as in the case of the South Wales coalfield, to which I now confine myself.
>
> At the commencement of the coal measure period a new set of conditions began to prevail. For a considerable period sand ceased to be deposited, and fine muds were laid down, occasionally alternating with

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[1] " Trans. Cardiff Naturalists' Soc.," Vol. xvii., p. 26.

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layers of argillaceous ironstone. At length the sea became entirely silted up, or, more likely, a slight elevation took place, raising its bottom to the level of the surface. Then a strong and vigorous vegetation clothed every available foot of space, and generation after generation of plants lived and died in succession, until a peat-like mass, covering a large area, was the result. Then came a gradual subsidence; the waters once more flowed over the surface, and beds of mud and sand were again deposited, covering up the vegetable matter and preserving it from further rapid decay. After this, at short intervals, fresh beds of sand and mud were laid down successively until the land-surface was once more on a level with the surface of the water. Then vegetation again spread over it, and in process of time produced another mass of peat-like matter, which in its turn became covered with sedimentary matter; and so on, until the whole carboniferous system, with its numerous beds of coal, had been completed. Such is the hypothesis of De Luc, which is the one adopted by most geologists of our time.

The other hypothesis starts with the supposition that the beds of coal have been formed in deep water, and that the vegetable matter was brought down in a state of minute divisions and maceration from some higher level and deposited in the same way as all other beds of sedimentary origin. M. Grand Eury, an eminent French geologist, is one of the chief supporters of this view. He contends that the vegetable matter grew in immense low-lying, marshy forests in the neighbourhood of great lakes, and that the nature of the vegetation was such that it quickly decayed under the influence of the climate then prevailing, producing a semi-fluid mixture of bark and leaves, and was floated out from time to time into the still waters, and, sinking to the bottom, formed a thicker or thinner sediment exactly in the same manner as the similar deposits of sand or mud.

Stigmaria, he says, were aquatic plants which grew in the water and left their remains embedded in the clays and other rocks which were formed at the same time. The higher lands were probably devoid of vegetation, and served only to supply the inorganic detritus which was washed into the lakes from time to time, covering up the deposits of vegetable matter with beds of sand and mud.

In support of this view he points out that the fossils of the coal measures, with the single exception of *stigmaria*, consist of flattened trunks of *sigillaria*, *calamites*, and other similar plants, from which the internal woody matter had decayed away before they were transported from the spot on which they grew. And lastly he explains the presence of upright tree trunks and stumps found in the rocks here and there by supposing that the waterside forests occasionally had an opportunity of spreading over a shallow or partially-exposed portion of the bottom of the

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lakes in a desultory manner, where they grew for a time, until they were cut off by the deepening of the water, or were killed by the sedimentary deposits accumulating around them.

I have carefully studied this part of the subject when examining seams of coal, and have never been able to adopt the theory that the great bulk of the organic matter which forms the seams grew on the spot. It is quite true that the underclay, with its fossil *stigmaria*, is an almost inseparable concomitant of every seam of coal, but the seam which rests upon it has no intimate connection with it by means of roots penetrating downwards. The separation is nearly always perfectly clean, and sometimes consists of a thin bed of shale. Again, we often find the seam divided into two or more distinct beds by partings. If the parting is followed over a large area, it is usually found that a thicker or thinner bed of shale is interposed between its surfaces, showing that the parting was due to some temporary pause, which allowed time for the deposition of inorganic matter. In some cases the intercalated inorganic matter may even thicken out to such an extent as to separate the two beds of coal by many feet or yards.

Sometimes a bed of shale, consisting of very fine laminated layers of sedimentary matter, divides a seam of coal into two parts, and is so intimately associated with the coal above and below it that it is impossible to tell exactly where the inorganic matter ends and the coal begins. In one part of a coalfield a bed of this kind may consist of cannel coal with conchoidal fracture; in another part it may be blackband ironstone, and elsewhere it may be black shale; and all three varieties are admitted by the advocates of De Luc's theory to be sedimentary deposits.

But coal lying above a layer of shale has no underclay, although its composition and mode of formation appear to be identical with those of the coal lying on underclay. From this it would seem that coal can be formed independently of underclay; and if so, we may infer that even where a seam lies directly upon the underclay, it need not necessarily have grown upon it, or be connected with it in any way, more than with the bed of coal lying on the shale.

I have said enough to show the reason why I lean towards Grand Eury's theory of the sedimentary origin of coal rather than towards De Luc's theory of its growth *in situ*. Nevertheless I admit that the subject is one of great difficulty, upon which it is impossible to pronounce with any degree of certainty.

He must say that he agreed with Professor Galloway in admitting that the subject was one of very great difficulty; but

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it seemed to him that the theory of the sedimentary deposition of coal, as here explained, when applied to the regular deposits of the true Carboniferous period, tended rather to create difficulties than to remove any of those inherent to the subject.

In the first place, it was to be noted that the chief conditions of the sedimentary theory (as above explained) were:—

(*a*) Vegetable supply derived from low-lying forests in the neighbourhood of great lakes.

(*b*) Vegetable matter deposited in a state of minute division or maceration.

(*c*) Carried out by currents from the forests into deep water and deposited exactly in the same manner as similar deposits of sand and mud.

Now, with regard to (*a*), it was obvious that the extent of the forest and duration of its growth must *pari passu* be greater than the area and thickness of the vegetable layer to be laid down; because (*b*) only that portion of the vegetable matter which had become reduced to a minute state of division or maceration was said to be floated away for deposition.

Then in regard to (*c*), it was inconceivable to imagine, under any circumstances, a river, or current of water (no matter of how quiet a character), that would continue to flow through the low-lying forests and carry out a continual stream laden with minutely macerated vegetable matter free from sediment or earthy material, and yet have sufficient power of current to distribute the humus over an area of many hundreds or thousands of square miles, in a fairly regular layer, during the immense period of time necessary for its accumulation.

Then again, seeing that the immense area of low-lying forests was essential to the sedimentary theory, would it not, it might be asked, be much more reasonable to assume that, if left undisturbed by currents of water, its periodic growth and decay, extending over a sufficient length of time, would produce a bed of vegetable matter *in situ*, of fairly even thickness, and free from sedimentary matter, which on a slight depression of the land would become covered up by the sediments brought in with the inflowing water, and thus in time become a seam of coal?

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Then again, when the currents of water became laden with sedimentary matter, sufficient to form the covering beds of sand and mud over the bed of vegetable matter deposited in the deep water of the lake, was it suggested that the immense low-lying forests from which the vegetable supply had been obtained became silted up at the same time, or were they swept bodily away by the water currents into the deep water of the lake, and fresh forest growth take place before there could be any further deposition of vegetable matter in the lake?

Whether the *stigmaria* in the underclay were the roots of *sigillaria* or not, it seemed to him that the fact of there being now no visible connection between the underclay and the coal deposited thereon was of little moment, because it was more than probable that as in nearly every case the transition of the vegetable matter into coal had completely obliterated (except to microscopical observation) the vegetable forms and tissues, and the subsequent pressure of the superincumbent strata had probably produced a smooth parting between the coal and the underclay; and as the *stigmaria* in the underclay had become fossilised by the usual process of transmutation, it seemed to him that one could hardly expect to find any visible continuity between the coal and the underclay. The only cases, he believed, in which a direct connection had been traced between the *stigmaria* of the underclay and the growth above, was in those instances where fossilised upright trunks of *sigillaria* (with the bark only converted into coal) had been found with fossilised roots spreading over, and penetrating into the underclay.

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Then as to the "partings," and alternating thin layers of sedimentary matter between beds of coal, he thought they might reasonably be accounted for by supposing, in the case of parting only, that a cessation of growth had been caused by some means—possibly by a slight subsidence of the land on which the vegetation grew sufficient to allow it to become covered with water for a time, without being subjected to any sediment-bearing currents; and that the water afterwards dried off, or the land became again slightly elevated, when the growth was resumed; and similarly, in the case of thin layers of shale intervening, that the covering waters were loaded with sedimentary matter, which became deposited, after which the vegetable growth was again resumed.

Then again, in those exceptional instances of small areas (of the true Carboniferous era) in which the deposits were generally of a lenticular form, and where the coal was found intimately associated with shale in finely alternate laminations, or sometimes changing from coal into black shale and *vice versa*; it appeared to him that such a condition of things might reasonably be accounted for by supposing that a small portion or portions of the coal-producing area might have been of a more swampy character, and the vegetable matter therein subjected to greater maceration, and at the same time that those areas were open to frequent slight inundations of water charged with fine sediment, not sufficient to stop the vegetable growth, but sufficient to produce in particular areas finely alternate laminated deposits of shale and coal, with other areas of purer coal, and others again almost entirely of black shale highly charged with vegetable matter.

He did not suggest, or think it essential, that underclay was the necessary concomitant of every separate layer of coal. All that was known was that it usually formed the base of each distinct coal seam.

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The assumption of M. Grand Eury that the *stigmaria* of the underclay were the remains of aquatic plants would infer that the underclay was formed in shallow water, and that the plants grew and died *in situ.* Questions naturally arose whether *stigmaria* had any special characteristics of the remains of aquatic plants, and if so, how it was that they appeared only in underclay.

In addition to the theory of the formation of coal *in situ*, and the theory of its deposition by aqueous action as a sedimentary deposit, there was the strong probability that some deposits of coal were formed from drifted vegetable and woody matter brought down by rivers, and deposited in deltas and lakes, and there silted up. In such deposits the probability was that the coal would be very irregular in thickness, and of very variable quality, as it would be liable to be much mixed up with the sedimentary matter carried by the water at the time of deposition. It would also probably occur in lenticular patches (possibly at times of considerable area), rather than in continuous seams over large areas, and one would not expect to find any bed of underclay associated with such coal. He looked upon such a formation as being entirely distinct from M. Grand Eury's theory of sedimentary deposition, as described by Professor Galloway, and in contradistinction, it might be called the "Drift theory," although both might be termed "subaqueous."

There was one test that he thought should be applied to the solution of all geological problems, and that was whether any similar processes were in operation at the present day.

In support of the theory of the formation of coal *in situ*, it might be mentioned that enormous masses of vegetable matter spread over very large areas, the result of long-continued years of repeated growth and decay, were to be found in many parts of the world, which, if buried with sedimentary deposits, would in

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> Some 40 miles by 25 miles in extent, has somewhat the appearance of an inundated river plain. In its centre it is 12 ft. above the surrounding plain. The soil to a depth of 15 ft. is formed of vegetable matter without any admixture of earthy particles. The surface is covered with mosses, ferns, and reeds, above which numerous shrubs and trees flourish, especially the white cedar and the cypress. On the surface lie innumerable trunks of large and small trees, with thousands of others blown down, which are buried at various depths in the black vegetable mass. They remind the geologist of the prostrate position of large stems of Sigillaria and Lepidodendron converted into coal, in ancient carboniferous rocks.

Some of the swampy jungles of Africa, India, and South America had very similar characteristics. Then there were the numerous ancient prostrate forests and peat mosses of their own country, and on the Continent, and elsewhere.

At Swansea Bay and at other places round the coast there were remains of submerged forests. One, in Liverpool Bay, had been described by Mr. J. McMurtrie.[2] That at Swansea consisted of a thick bed of stiff blue clay, upon which rested the upright stumps of trees with roots spreading out as they grew, surrounded by fallen trunks, branches, and leaves, all more or less converted into a dark brown peaty mass, in some parts nearly black and homogeneous in structure. The roots of the trees could be clearly traced and followed deep into the blue clay, the upper portion of which for some distance down was reticulated with rootlets. The action of the tide had in many places denuded the clay of the bed of vegetable matter, and its structure could be seen in all its stages. It was surprising how very slowly the action of the tidal waters, which were often most tempestuous, wore away the vegetable deposit. On some parts of the seashore it was from two to three feet thick,

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[1] Lyell's "Principles of Geology," p. 724.

[2] "Proceedings South Wales Institute of Engineers," Vol. xx. p. 22.

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but where it had been cut through as in the construction of the South Dock, and the foundations of gas works and other buildings out of reach of the sea, it was as much as 6 ft. to 8 ft. thick, covered by drifted sand. No geologist on seeing it could doubt that it contained all the elements for the formation of a seam of coal.

Then in regard to the "Drift theory," the great deltas of the Mississippi, Orinoco, Ganges, and many other great rivers bore evidence of the enormous amount of drift-wood and vegetable matter brought down annually and buried, in sometimes fairly even masses, in the silts carried down by those great rivers.

The great plain formed by the waters of the Mississippi contained about 31,200 square miles, the existing delta alone having an area of some 14,000 square miles, and a width of 90 miles on the coast line. For the first 100 miles from its mouth, the river falls 1·80 inches per mile. Lyell says[1]:

> One of the most interesting features of the great rivers in this part of America is the frequent accumulations of what are termed "rafts," or masses of floating trees brought down by the river, which have been arrested by shoals or other obstructions. One of the largest of these was formed during thirty-eight years prior to 1816, in one of the branches of the Mississippi, when it formed a continuous raft 10 miles in length by 220 yards in width and 8 feet deep. The whole rose and fell with the water, and was covered with growing bushes and trees. It went on increasing until 1835, when some of the trees upon it had grown to a height of 60 feet. Steps were then taken to remove the obstruction, a work which occupied some four years. The prodigious quantity of wood annually drifted down the Mississippi was a subject of geological interest, not merely illustrating the manner in which abundance of vegetable matter becomes in the ordinary course of nature embedded in the estuary deposits, but as attesting to the constant destruction of soil and transportation to lower levels, by the tendency of rivers to shift their course. It was found in excavations at New Orleans that even to a depth of several yards below the sea evel the

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[1] Lyell's "Principles of Geology," p. 267.

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soil of the delta contains innumerable trunks of trees layer above layer.

Enormous quantities of drift-wood were also carried down by the Mackenzie River (one of the Canadian rivers running into the Polar Sea). In its course it passed through the Slave Lake, which vied in dimensions with some of the great fresh-water seas of Canada. Lyell's description was most interesting; he says[1]:

> As the trees retain their roots, which are often loaded with earth and stones, they readily sink, especially when water-soaked, and accumulating in the eddies of the river, form shoals, which ultimately augment into islands. A thicket of small willows covers the new-formed island as soon as it appears above water, and their fibrous roots serve to bind the whole firmly together. Sections of these islands are annually made by the river, assisted by the frost, and it is interesting to study the diversity of appearances they present, according to their different ages. The trunks of the trees gradually decay, until they are converted into a blackish brown substance resembling peat, but which still retains more or less the structure of the wood. Layers of this often alternate with layers of clay and sand, the whole being penetrated to the depth of four or five yards or more by the long fibrous roots of the willow. It was in the rivers only that sections of these deposits could be observed, but the same operation goes on, on a much more magnificent scale, in the lakes through which the Mackenzie River and its tributaries run. A shoal, of miles in extent, is formed on the south side of Athabasca Lake, by the drift timber and vegetable debris brought down by the Elk River. The Slave Lake itself must in process of time be filled up by the drifted matter daily conveyed into it by the Slave River. Vast quantities of drift-timber are buried under the silts at the mouth of the river, and enormous piles of it are accumulated on the shores in every part of the lake.
>
> The banks of the Mackenzie River display almost everywhere horizontal beds of wood coal, alternating with bituminous clay, gravel, sand and friable sandstone, and sections of such deposits are now evidently forming at the bottom of the lakes which it traverses.
>
> Notwithstanding the vast forests intercepted by the lakes, a still greater mass of drift-wood is found where the Mackenzie reaches the sea, in a latitude where no wood now grows, except a few stunted willows.

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[1] Lyell's "Principles of Geology," p. 744.

At the mouths of the river the alluvial matter has formed a delta of islands and shoals, where a great deposit of coal will be formed at some distant period.

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He had been unable to find any examples of the sedimentary deposition of vegetable matter going on at the present day, in support of M. Grand Eury's theory.

It might now be asked how far the general characteristics of the South African coal deposits, and particularly those of the Transvaal, agreed with either of those theories, or what were the probable conditions under which the seams were formed.

With reference to this question generally in South Africa, Professor Green says[1] :—

> The rocks (Kimberley shales and overlying strata) lie in a great saucer-shaped basin ; but the saucer is so flat that the strata are everywhere practically horizontal.
>
> The coals in some cases have suffered largely from contemporaneous denudation before the beds next above them were laid down. Looking at the coarseness of some of the grits overlying the coals, the wonder is that any of the coal at all survived the conditions that must have prevailed shortly after its formation.
>
> So far as I could discover, there is an entire absence of underclay below the coal. At the Indwe Colliery the coal rested directly on a hard, closely grained, laminated, micaceous sandstone. There were a few vegetable impressions on the planes of bedding, but I could see nothing like rootlets.
>
> The coals in the Cape Colony vary enormously in thickness and value (quality) from place to place, and there is some reason to think that the coals were originally deposited in detached patches ; and it is difficult and premature to form any just conclusion as to the extent or value of the deposits.
>
> All the coals that I saw are more or less laminated ; some of the layers appear to be all coal, often bright and lustrous—other layers are black shale. But there is a third kind of layer, the like of which I do not recollect to have seen in any but these coals ; they consist of a large number of very thin laminæ of coal and numerous still thinner films of hardened black mud, which coat the surface of each coal lamina, and

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[1] "Quart. Journ. Geol. Soc.," Vol. 44, pp. 249–253.

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> separate it from those above and below. This was shown in a very pronounced form in the coal worked at Cypher Gat.
>
> All the coals which have been analysed are extremely impure, containing from 21 to 30 per cent. of ash.
>
> My notion of the way in which these coals were formed is somewhat as follows: The great lake in which the Molteno Beds were laid down became largely filled up. A swampy surface was formed, dotted over with pools and small lakes of various sizes and depths. In these basins, or in some of them, alternating layers of vegetable matter and mud were laid down. The evidence is far from conclusive, but is not incompatible with the view that the coals are of subaqueous origin.

The description given by Professor W. Galloway [1] of the Cape Colony coals agreed on the whole very much with that of Professor Green. He says:—

> The strata which constitute the Coal Measures (Molteno Beds), as well as the formations immediately above and below them, lie almost horizontally. Very few faults are to be seen, and there are no foldings or contortions of the strata of any moment.
>
> The only workable seam of coal found within the Cape Colony lies at a height of about 300 feet above the base of the Molteno Beds. It consists of alternate layers of coal and shale, and is thicker towards the east than towards the west. It is known for a distance of some sixty miles, from Molteno on the west to Indwe on the east, but in many places is hidden by volcanic rock.
>
> The thickness of the seam varies much in different localities. The most remarkable feature is the large amount of ash which is common to all the coal worked in Cape Colony.
>
> I have long held the opinion, in common with many eminent mining men, that, with few possible exceptions, most of the seams in this and other countries, including South Africa, have had a subaqueous origin.

In the paper under discussion, Mr. W. Forster Brown, in describing the coal seams of the Transvaal, points out that no underclay had been found associated with the coal; that the seams varied very considerably in thickness within short distances, and that the quality also varied very much even in the same seam; that the appearance of the coals differed con-

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[1] "Proceedings South Wales Institute of Engineers," Vol. xvii., p. 67.

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siderably, but generally might be classed into two types—one a coal of stoney appearance with no signs of lamination, the other a bright laminated coal. The percentage of ash varied from 2 per cent. up to 21 per cent. The amount of moisture in the coal was very noticeable, being from 2 per cent. up to 6·5 per cent. The coal in the western area was a fair steam coal, whilst in the northern and eastern portions there were good smithy and coking coals, and also steam and house coals of good quality. Mr. Brown further stated that in the western portion the coal measures were shallow and rested directly upon quartzite, whilst in the eastern portion they were probably 1,000 feet in thickness, and that their outcrop rested upon igneous rocks, which would show that in the Transvaal the Kimberley shales and Karoo beds had thinned away. The author's view of the question of the deposition of the beds of coal was given on p. 138, Vol. xx., of the Proceedings.

In a paper read before the North of England Institute of Engineers last month, Mr. W. T. Hallimond, who had had some fifteen years' South African experience, and was formerly in charge of collieries at Boksburg, and was now in charge of the Rand Collieries, gave some very interesting information in regard to the Transvaal coal deposits. The following are abstracts:—

> The coal of the Transvaal is undoubtedly all of the same age, although the beds are not continuous, but are formed in basins, and are very variable, both in quality and thickness as well as area. This variation prevailed as much in the bituminous coals of the Middleburg district as in the steam coal basin of Boksburg, Brakpan, and Springs districts.
>
> At two collieries in the Boksburg coal basin the Banket bed (quartzite) has been struck not far below the coal, and at the Phœnix colliery a heading driven south in the coal came against the tilted Banket beds. The Boksburg coal area is a complete basin, surrounded by the quartzite formations.
>
> At the Rand Collieries at Brakpan, Cassel, Great Eastern, and

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Clydesdale Collieries—all in the same district—the shafts, after going through the coal, penetrated a conglomerate of sandstone and quartzite pebbles.

The seam in the Middleburg district comprised bright bituminous coking coal 4 feet to 6 feet; dull coal (beneath) 7 feet to 8 feet; but he had found the bright coal turn to dull coal, and also at times contain pockets of black, shaley stone, and the total section to diminish to 5 feet, and then increase to 15 feet; the undulation in every instance being in the floor of the seam.

He had found no underclay in connection with any of the seams of coal, and there was a great scarcity of fossils. He was of opinion that the coal deposits were of subaqueous origin—that is, that the vegetable matter now found in the form of coal was borne by water and deposited in the basins in which it now occurs.

With regard to the Natal coal deposits, Mr. R. A. S. Redmayne (before quoted) says[1] :—

> One cannot but be convinced that the Natal formation is contemporaneous with the Cape Colony Coalfields. The area over which the formation extends is enormous. . . . In reality, however, the coal deposits of Natal are spread about in beds of coal of variable quality, of no great extent individually, and often reduced by denudation.
>
> The reasons advanced to prove that the Natal Coalfields are of subaqueous origin, are :—
>
> (1) Fossil remains are exceedingly scarce either just above, below, or in the coal. At Boston Mills there is a 9-in. seam of coal resting on a bed of shale, in which the roots of coal plants are constantly found; and the roof, also shale, contains numerous leaves of coal plants; while at a few other places, viz., Estcourt, Weston, the Mooi River, and Lennoxton, plant remains are found; but as a general rule they may be considered as extremely rare. The finding of fossils in a few isolated cases does not militate against the subaqueous theory.
>
> (2) The extraordinary variations in the thickness of the seams of coal in a very short distance—in one case thinning out to one foot, and then in a few yards increasing to three feet, and again in a short distance thinning out; and also the great variation in the thickness and character of the bands separating the coal.
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> (3) The total absence of any underclay, the floor of the seams being usually sandstone, and sometimes shale.
>
> (4) The instance mentioned by Dr. Sutherland, where, in the New-

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[1] "Transactions Federated Institution of Mining Engineers," Vol. 4, p. 555.

castle district, there was found imbedded in the coal a fragment of granite which weighed about 1½ lbs., goes to prove those coals to be drift material.

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(5) The specific gravity of the coal is high, showing the presence of earthy impurities, which is borne out on analysis; and on very close examination layers of earthy matter are observable in some of the coals.

It would appear, therefore, there was a general concurrence of testimony that the South African coals—

(*a*) Were probably of Triassic age.

(*b*) That they are not associated with underclay (except as mentioned by Mr. Redmayne, at Boston Mills); and that fossil remains were extremely scarce.

(*c*) That whilst the strata of the coal measures extended over an enormous area, the deposits of coal lie in detached patches or basins, and probably at different horizons, rather than in continuous seams over greatly extended areas.

(*d*) That the seams vary very much in thickness in short distances; and also vary very much in quality.

(*e*) That with few exceptions the coal is very impure, containing a large percentage of ash.

Now he thought all those general characteristics were more in consonance with the Drift theory of deposition, than either with the sedimentary theory, or that of the formation of the coal *in situ*.

There was clear evidence that strong currents of water prevailed during the greater period of the deposition of the Molteno Beds (coal measures). Though some of the sandstones were finely grained, the greater part of that deposit was formed of very coarse grits, made up to a considerable extent of large grains of quartz. Those grits frequently passed into conglomerates containing pebbles of white vein quartz; and still

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coarser conglomerates were occasionally met with, containing large boulders of quartzite.

Frequently a sandstone of coarse grit formed the covering of the coal deposit; and in many cases the coal itself had evidently suffered by contemporaneous denudation.

Whether the coal deposits were formed by currents of water breaking up the vegetable growth and accumulations of years, which might have existed possibly over the same area as the coal measures, and thus have laid bare some areas, whilst in others the vegetable matter was drifted by the currents and accumulated more or less in patches or basins, in irregular layers and mixed with silt, before being finally covered up by a larger inflow of water-borne sediments and grits; or whether the vegetable matter was brought by rivers from a greater distance (as in the case of the Mississippi and other large rivers at the present day), and formed an estuarine deposit, there did not appear to be sufficient evidence to determine; but taking into consideration all the circumstances, he was rather inclined to think that the former might possibly be the more reasonable conjecture.

Mr. Henry K. Jordan.

Mr. Henry K. Jordan said he welcomed the Paper on the ground that it afforded a concise statement of another coalfield in a distant part of the world. He thought the first impression which everyone must have on reading the Paper was the enormous area of the South African coalfield. It was stated by the author of the Paper to be 60,000 square miles; that was equal, almost exactly, to the total area of England and Wales. Was it really one, or a disconnected coalfield? In a country which had been comparatively so little investigated, might it not well be that that huge coalfield was separated pretty much as South Wales was separated from the coalfields of Bristol, North Wales, Forest of Dean, and Shropshire? If it was really one gigantic coalfield, then they

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had this interesting fact, that from the time of its deposition, this coalfield had been practically undisturbed. The great movement which took place in Miocene times, and altered the appearance of Northern Africa, and also so greatly modified the appearance of Europe and the North British Isles, had not affected the area under notice at all. Then he would like to ask the author whether, since he published the Paper, he had any further evidence as to the age of this coal? Was it carboniferous, or triassic, or was there anything to show what the age of the coal was? He would like to ask Mr. Bailey if the limestone he had spoken of had any fossils included, so as to elucidate the question as to the age of this coal.

The question as to the high percentage of ash had also been noted by the two previous speakers, and he would not dwell upon it, except to say that he found, by taking an average of the eight analyses given by the author, it worked out at 12 per cent.

With regard to the formation of the coal, two theories had been advocated; one that it had been formed *in situ*, and the other that it was of subaqueous origin. Personally, he would prefer the word "drift" to subaqueous. But he thought it was quite possible that coal had been formed by both methods; that coal formed *in situ* had its thickness added to occasionally, and even a separate coalfield might have been formed by vegetable matter drifted down by currents of water. The author spoke of currents of water in his Paper, and they had abundant evidence of the existence of currents of water during the coal formation. In many of their coal seams there were areas in which the coal was non-existent. He did not say that in all cases it had been washed away by water, for it was possible that in some of those non-productive areas the surface might have been unsuitable for the growth of vegetable matter —either too high or too low. Anyhow, they would sometimes

Mr. Henry K. Jordan. find that where the coal was not existent, it was due to currents of water which flowed there and transported the vegetable matter from that locality. He remembered a colliery with which he was connected when a youth, where the whole of the coal, which was usually 5 ft. to 6 ft. thick, was absent for a considerable distance, whilst in an adjacent area it was 10 ft. thick, and it was clear that the coal had been washed away from one area and had been piled up in the other. They had plenty of evidence that currents of water existed whilst the coal seams were being formed, and they might say truly, he thought, that the thickness of the coal seam was determined by the currents of water, which, according to their force, brought down either silt or grains of sand, which, by covering up the vegetable matter, terminated its growth, and thus formed the roof of the coal seam. They had evidence that these streams of water were also of great strength, sometimes breaking up entirely the seam of coal over which they flowed. In the Bridgend district, the roof of the Rock Vawr seam was mixed up largely with pebbles of coal derived from the seam on which the roof lay. In the neighbourhood of Pontypridd, there was only a short time ago to be seen, in a cutting at Glyn Taff, large lumps of coal embedded in the rock on the right-hand side going from Pontypridd to Caerphilly. In a quarry on the opposite side of this cutting, a bed of fireclay was to be seen, which in his opinion had been the floor of the coal seam from which those lumps of coal were derived. At Dinas, on the roadside, they would see a coarse sandstone, laden in places with coal detritus and carbonaceous matter, which had been derived from the coal seam immediately beneath. So they had ample proof that currents of water, which sometimes resulted in wash-outs, occurred during the formation of coal seams. He would content himself with those observations, and only further say of the Paper that it

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contained an amount of useful information which would be of great service to those who had cause to study the district of the Transvaal professionally.

Mr. G. E. McMurtrie.

Mr. G. E. McMurtrie said he should like to ask the author one or two questions in regard to the system of working adopted in these collieries. The system of working apparently was that known in the north of England as the pillar and stall. There bords were driven 4 or 5 yards wide, and headways 7 ft. In the Transvaal, apparently, the bords were 30 ft. wide, and the pillars 15 ft. The proportion of coal thus left, compared with that worked, appeared very small if the pillars were intended to be worked. In the north of England, pillars which were formerly made 31 ft. by 11 ft., had been increased to 20 yds. by 20 yds., and again to 20 yds. by 40 yds.; and he believed latterly in Yorkshire that pillars were left even larger than that. Possibly it was never intended to recover those pillars in the Transvaal. It would be interesting if Mr. Brown could give them some more details as to the method of working the different portions of the seam. They in England had a 10-yard seam in Staffordshire, which had a special system of working of its own, and it appeared to him that in Africa, where they had even a greater thickness, some special method of working must be adopted entirely different to what they were accustomed to in England. He had intended to have asked Mr. Brown as to the abundance or otherwise of timber, but Mr. Bailey had already told them that the supply of timber was very short, which explained the small amount of timbering that was done. It seemed to him that, with such a width of stall as 30 ft., to timber only where they had a wash-out in a seam that apparently produced no dirt was hardly wise. The total waste of small coal appeared to him extraordinary. One would have thought that coal of that description might have been used in the boilers at the gold mines, especially now

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when every effort was being made to economise, and wherever waste had taken place to cut it down. The type of boiler used was multitubular; in the north of England he remembered seeing a few years ago Lancashire boilers being fired by means of mechanical stokers, with coal which contained 40 per cent. of dirt. That seam was worked solely for this purpose as an economy, by Mr. George May. The proportion of nuts to large coal appeared very great. At their own collieries they made a proportion of something like 9 per cent., but here they made a proportion of 25 per cent. Possibly that might be due to the size of the nut. In England nuts generally comprised the coal that passed through an inch and a half mesh, and over a mesh of three-quarters of an inch. He should also like to ask why the gold mines were not connected to the railways. He understood they had some peculiar ideas in that country on this point, and possibly that might have something to do with it; but it did appear to him that the mines were in a somewhat critical state. Every effort should therefore be made to produce economically, and when they could buy coal at the pit at about 10*s.* a ton, and they had to pay at the mine 20*s.* to 30*s.* per ton when delivered, it appeared to him that there was scope for considerable economy by connecting the mine to the line by sidings. The plants that Mr. Brown gave appeared very small when compared with the capital of the companies. Take the Cassel Colliery, with a pair of 11 by 24 winding engines and three boilers, and they had the large capital of £500,000. He did not know whether these collieries had arrived at the time when mechanical haulage was necessary; Mr. Brown might give them some information about that. In the plants he had given no reference was made to mechanical haulage, and he therefore took it that at the time Mr. Brown visited the Transvaal no mechanical haulage was at work. The Paper was written about two years ago, and at

Mr. G. E. McMurtrie. that time Mr. Brown specially referred to the Brakpan, Springs and the Cassel Collieries, and he stated that four other collieries were in process of development. Could Mr. Brown give them any information as to how far the development had gone, and whether those collieries were now producing coal, and if so upon what scale? As he understood it, the growth of the coal-mining industry appeared to advance quite as quickly as the growth of the gold-mining industry, and unless further outlets were found for the coal, with such a large field as the Transvaal possessed, that country would very shortly be in the same unfortunate position they were now in England, of being able to raise far more coal than they required for their own purposes, and able to pay but a modest dividend at the best upon the capital invested.

The President. The PRESIDENT said if no other gentleman had anything to say he would ask Mr. Brown to reply to the discussion.

Mr. W. Forster Brown. Mr. W. FORSTER BROWN said that with regard to some of the questions asked by Mr. McMurtrie, he believed the new collieries mentioned were now in operation, and the output of coal had gone up half a million tons from the time he was in the country. The explanation of the large capital was due to the fact of the large profits made, and the people who floated the companies secured most of it. With regard to the connection of the gold mines with the railway, he believed that was a grievance against the railway company—that it gave no facilities for connecting the gold mines, and they had to do the best they could.

The reason why the small coal was not used was that it was of too dirty and poor a quality. They could get steam with the present coal, but he should very much doubt whether they could do so with the small coal. As far as the system of working was concerned, he could only speak as to what was actually being done when he was there, and he did not know what

Mr. W. Forster Brown. reasons they had for driving their stalls 30 ft. They used very little timber, and the pillars of coal served in the place of timber.

In reference to Mr. Jordan's remarks, the area stated in the Paper as coalfield was not meant to show that the whole was necessarily coal-bearing. That was the area that was supposed to be covered by the formation in the middle of which the coal measures occurred. With reference to the age of the coal measures, M. L. De Launay, a French gentleman, had written a very interesting book on the coal seams, and he placed the Transvaal coal measures in a different horizon to those of Cape Colony. He placed the Transvaal coal measures in the beds lying below the Molteno beds in which the Cape coals were supposed to occur, and in the Trias, and Mr. Draper, the well-known geologist, also placed them in the Trias. Mr. Jordan considered that the thickness of the seam might be added to by the currents of water, but he did not seem to have taken into account that the whole of the coalfield might have existed greatly below the level of the sea or inland lake when the sandstones were deposited on the top of them. In relation to the remarks that Mr. Huxham made, if M. L. De Launay's conclusions were correct, it would be quite sufficient to account for the Cape Colony coals and those of the Transvaal being of a somewhat different quality. With regard to the coal at Heidelburg, apparently—not having seen the analyses—it was a continuation more or less of the same seam as at Boksburg, and throughout the western part of the coalfield the deposit was very thick.

With regard to the origin of the coalfield, the question laboured under the disadvantage of not having sufficient data to put either theory at rest. Personally he could not bring himself to believe in the drift theory in a large coalfield like the one under review. In small basins, such as some of the

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coalfields of France, one could understand it; but in such a large field as this, it appeared to him that the vegetation must have grown where the coal had been formed—probably the real reason being that, so long as they had the vegetation, the actual conditions required to convert it into coal need not necessarily be the same.

He was interested to hear of Mr. Bailey's investigations, which seemed to show that the good coals of the Transvaal lay on the northern and eastern part of the field, and not on the west. Mr. Bailey gave an analysis in an extract from the *Western Mail.* He quite agreed with Mr. Bailey. He saw nothing of such good quality in this field, and he could say that the coals he saw he tested in relation to Welsh coal—obtained from Delagoa Bay—to arrive at an approximate value of the two coals, and the nearest approach to Welsh coal they found was on the eastern part of the field, and the percentage was about 17 per cent. of steam-power below the coal they obtained from Delagoa Bay. He could not say what Welsh coal it was, but they were tested under the same conditions as to producing power. He had no doubt that the eastern coals of the Vaal would enter into competition with Welsh coal on the shipboard. If they could get a coal 20 per cent. below in value, and 30 per cent. below in price, it was sure to be used for most purposes, added to which the railway, being all on the down-grade, rendered cheap rates from that portion of the Vaal to the coast comparatively easy. Admitting that Welsh coal could be reduced in price to 35*s.* per ton where it was at present 45*s.*, and the Transvaal coal—of a quality of from 17 to 20 per cent. below—could be landed at 20*s.* a ton, no doubt in future it would procure a market there in opposition to Welsh coal, added to which a large trade was being done in timber with the East Indies. The boats that came into Delagoa

Mr. W. Forster Brown. Bay returned in ballast, and there was no reason why the coal should not be carried to the East Indies, to compete with Welsh coal in that quarter. His impression of the coal seams and the roofs likely to be met with, was that the requirements in the way of mining timber would not be very large. At Johannesburg very large plantations had been started for the benefit of the gold mines, and he believed in a few years they would be quite ready for cutting. He did not think there was anything further to reply to.

The President. The President said he had very great pleasure in proposing a cordial vote of thanks to Mr. W. Forster Brown for his very able Paper. When he paid his second visit to South Africa—which he understood was in the near future—he hoped he would write a further paper upon this important matter.

The discussion then closed.

Discussion on "The Strength of Corrugated Sheet-Iron."

The President. The President said the next business was to discuss Prof. Elliott's and Mr. Wilson's Paper on "The Strength of Corrugated Sheet-Iron."

Mr. Thomas Evens. Mr. Thomas Evens said that he thought Professor Elliott had treated the subject very fully. As an old hand, he (the speaker) usually sent particulars, and had more or less trusted makers to send him what was wanted. He should now, however, be able to refer to Professor Elliott's tables, and ascertain what thickness of sheet would be necessary for the work required. He thought ordinary galvanised circular roofs were very well for common work to put over the sheds, but he preferred black plates a little thicker, rather than galvanised plates a little slighter at the same price, laid flat on timber or other framing, and they would last as long a time if kept well tarred. If damaged in any way by accident, or worn thin, an ordinary carpenter could put a fresh sheet on. **Mr. Thomas Evens.**

Mr. J. VAUGHAN said, in addition to the authorities quoted by Professor Elliott and Mr. Wilson, there was some very useful information in a little work by Skelton on corrugated iron. They had there the various sizes in which the corrugated iron sheets could be obtained, the courses, and depth. Compared with a roof covered with slates, if they had to make the principals and purlins in order to carry the corrugated sheet, there was in point of cost very little in favour of the sheet. They could obtain the slates nearly as cheap as they could obtain the sheets, and in one case they had a much more durable structure than they had with the corrugated sheets. He had seen in one instance corrugated sheeting, 16-gauge, well painted with three coats of paint, completely corroded in twelve months, and it had to be replaced by a slate roof. A very objectionable feature of corrugated sheeting was that it formed a very efficient condenser. Water rapidly condensed on the roof, and dropped down on the machinery, and that was an evil which they did not get with slate. For temporary purposes a self-supporting roof could no doubt be made cheaply, and would be tolerated, and they knew it was very frequently used for permanent structures, but on buildings of 30 ft. to 40 ft. it would be a risky thing to use. **Mr. J. Vaughan.**

Mr. T. H. BAILEY observed that the Paper was very full of information, and he doubted very much whether any engineer would go to the trouble that Professor Elliott had done. It was very well to have Professor Elliott's work, which would no doubt be of great use. If they assumed the value of the Paper from a professional standpoint—and of such there could be no doubt—it might be open to some objection from a prac- **Mr. T. H. Bailey.**

Mr. T. H. Bailey. tical view. The essence of the Paper was in the tables given on page 229, which was the theoretical view, and on page 239, which was the practical view. He hesitated to express his opinion on the calculations, the accuracy of which must be assumed, and the authors had conferred a benefit upon the Institute by showing that there was a theoretical as well as a practical side of the subject, of which he feared some of them often lost sight.

Referring to the remarks at the foot of page 223, he should doubt, and he certainly did not know of a useful fact or formula being obtained from Professor Rankin's "Civil Engineering." They were correct, but he considered them practically useless.

The whole of the Paper appeared to turn on the use of *thin* corrugated sheets, which sheets for roof coverings and the like were undoubtedly very useful, and might be employed with advantage oftener than they were. As the Paper pointed out, the corrugated sheet coverings could be most advantageously used as part of the framed structure of the roof with great economy. Every engineer knew, however, that thin sheets, exposed to the atmosphere, rapidly deteriorated. There was no reserve of material, and when oxidation once set in the sheet was practically doomed. They used corrugated iron in sheets, taking advantage of its corrugated strength, but they always took into consideration the inherent shortness of its life. He would continue to rely upon his own judgment and experience, and would not take the trouble to make any elaborate calculations as those set forth in the Paper. He failed to comprehend the possibility of any engineer of experience making calculations as to the strength, for instance, of plates of a thickness of 24 B.W.G., or equal to 1–50th of an inch. He would do nothing of the kind; he would use just such a plate as would meet his purpose for the time being, allow for its decay, and provide for a reinstatement in due course.

Calculations as to *thick* plates were useful, and indeed necessary. Corrugated plates with deep corrugations, say 4 in., and wide pitch, say 12 in., and $\frac{1}{4}$-in. to $\frac{1}{2}$-in. metal, had been for some time in use on the Continent for bridge and other floorings. They were coming into use in this country, and were found to have many advantages. The larger corrugated sheets were usually described as trough flooring, and now for many years had been in constant use for heavy work, and for that purpose they were vastly efficient and economical. They were now about constructing some bridges over a colliery railway in Warwickshire, and proposed to use this flooring to carry the county roads over it. The strength of these trough floorings was computed much in the same way as was set forth in the Paper, and since the manufacturers had laid themselves out to supply such corrugated sheets or trough flooring the use of them had been largely extended. There were several kinds in ordinary use, made to carry various weights and strains, and any maker would tender for any requirements of the engineer. **Mr. T. H. Bailey.**

Mr. ARTHUR J. STEVENS said there was one point that had not been touched upon in the discussion, and that was the manner in which the sheets were put up. They found different experiences. For example, of two roofs, one lasted twenty years, and another, put up under similar conditions, lasted six or seven. A great deal to do with it was the way the sheets were dealt with. If they put up a roof immediately they received the sheets from the maker, they must not expect good results. They must keep the sheets in an absolutely dry place. If they dipped them in oil, or dipped them several times in the best liquid red lead, and then painted them and put them up, they would very likely double the life of the roof. **Mr. Arthur J. Stevens.**

Mr. SYDNEY F. WALKER said it appeared to him that the question was not whether corrugated iron sheets were the **Mr. Sydney F. Walker.**

Mr. Sydney F. Walker. best things to be used for buildings, temporary or otherwise, or what their value was as a building material, but what their strength was as compared with ordinary sheet-iron. The process of corrugation, as he understood it, brought in the form of the arch. In an ordinary sheet of iron, if they had a weight, or what was the equivalent of a force of any kind, such as a force of wind, they had a simple mechanical moment dependent on the weight and resistance above them. If they had corrugations they had another state of things altogether. They had two arches, such as mining gentlemen used in their mines, one above and one below, which altered the whole condition of the problem, and made it something of the complicated nature of the formula which Prof. Elliott had given them. The net result of these corrugations was that they were able to use a much slighter material for certain work, and of course a very much cheaper material, and therefore he presumed they could build their house or buildings very much more cheaply. That he took to be the object of the Paper, which in that case hardly admitted of discussion. The net result of the Paper was that it gave in tabular form an equivalent in corrugated sheet that could be used in place of plain sheet. With regard to the remarks that Mr. Bailey had made about the use of mathematical formulæ, he supposed they all avoided mathematics as far as they could, but the tendency of modern engineering was to emphasise the use of mathematics more and more. They were constantly faced with problems which could only be solved accurately by mathematics. What Dr. Elliott had done was to work out the problem mathematically, and test it with his apparatus at the College, and had shown that he had found the results to agree. The point Mr. Stevens mentioned about plates not lasting was quite right. He should say the cause was chiefly due to galvanic action. If they left two plates, apparently alike, with moisture between, or in such a condition that moisture could get between, they would have galvanic action set up between them, and they would be eaten away very much more quickly than if there was no galvanic action. **Mr. Sydney F. Walker.**

Prof. A. C. Elliott. Professor A. C. Elliott, in reply, said he felt that the Paper required just a certain amount of apology for the mathematics, but as they would observe, the mathematics were compressed in the appendices, only there were some mathematical expressions used in the nature of formulæ, and he believed no one there would take it as a compliment if he were told that Molesworth's Pocket-book was of no use to him. He expected any one of them would resent that. Mr. S. F. Walker, speaking about mathematics, had hit the nail on the head. They attempted to do something for the designer. The self-supporting roof had been before the public for some years, but he was not aware that anybody had made an attempt to work out the strains. He had tried to do what he could to simplify the matter to such an extent that nobody need be bothered in working out results. With reference to what Mr. Evens said, that really was the present state of affairs. Most of them had been content to give the orders to the makers, but the makers at the present time tried to cut things very fine, and those of them who had given any orders knew that it was a very hard thing to assure oneself that the plates that were being put up were adequate, and it was very considerable trouble to assure themselves that the material they got was up to the specification, if they had taken the trouble to make a specification. He hoped what they had done would do something to help the preparation of specifications. He understood that Mr. Bailey said Professor Rankin's formulæ were no good. Well, he would hesitate to say that it was not a very good work indeed, but he expected that the formulæ in the Paper were a little more accurate. He also understood Mr. Bailey to say that the

Prof. A. C. Elliott. calculations applied to thin sheets were of no use, whereas the same calculations applied to thick sheets were of great use, especially in regard to some sections that were coming into use for bridge flooring and fire-proof flooring. They were very important indeed, but this was not a paper on bridge or fire-proof flooring, although the subject was mentioned. Mr. A. J. Stevens mentioned a point about the durability. These roofs were sensitive, and they required a very large amount of attention both during erection and after they were erected. He agreed with Mr. Stevens that the plates required to be examined before and after construction. Mr. Walker spoke about galvanic action, and that was a fruitful cause of disaster. Mr. Vaughan compared corrugated roofs with slates and said there was very little in it. He supposed in this part of the country that was perfectly true, but there were other parts of the country, and places abroad, where slates were not nearly so plentiful, and very much dearer. In fact, they were face to face now with a possible rise in the price of slates. He could say more that would be more or less interesting, but he had gone through the most important points. He thanked them for the kindly attention they had given to the Paper.

The President. The President proposed a hearty vote of thanks to Prof. Elliott for his very able Paper. He was sure they were fortunate in having a member who was not only able to make such elaborate tables, but was willing to do so. It was not only a Paper written for the sake of discussion at a meeting like that, but it was a work of reference for engineers whose duty it was to design roofs, or other buildings, by which they would need the use of corrugated iron sheets. He had very great pleasure in proposing a very hearty vote of thanks to Prof. Elliott for his Paper.

The discussion then closed.

Professor W. Galloway then read the following Paper (p. 304) on "Subsidences caused by Workings in Mines."

A Paper by Mr. W. J. Heppell on "The Cost of Secondary Horse Haulage" was taken as read, and ordered to be printed in the Proceedings. (See p. 343.)

A vote of thanks to the President closed the proceedings.

SUBSIDENCE CAUSED BY THE WORKINGS IN MINES.

By Professor W. Galloway.

When the dimensions of an excavation exceed certain limits, which are dependent in every case upon the nature of the ground surrounding it, collapse takes place and subsidence follows as a necessary consequence. The direction in which the ground will break, and the amount of subsidence that will follow, cannot be accurately determined beforehand. It is therefore obviously safer to draw conclusions from actually observed facts as presented in the course of mining operations, rather than to be guided by merely theoretical considerations.

This question has been the subject of much controversy and litigation; it has given rise to the expression of many irreconcilable opinions; it always comes to the front when the workings in mines are likely to affect the surface of the ground, or important buildings, or other works established on the surface; it is recognised in this connection in several Acts of Parliament (notably so in the Railways Clauses Consolidation Act); and as it was discussed to some extent at the last meeting[1] of this Institute, the writer thinks that this occasion is not inopportune to lay before the members some of the views that have been expressed, and the observations that have been made, regarding it by some of the eminent engineers of the Continent.

[1] Proceedings S. Wales Inst. of Engs., Vol. xx., p. 208.

When an object on the surface is to be preserved from the damaging effects of subsidence, the usual practice in this country is to leave a pillar of liberal dimensions vertically below it, and to work round about the pillar without any other special restriction. This practice appears to indicate the existence of a general belief that the break of the ground above an excavation takes place more or less vertically round about its edges, and this may be termed the Vertical Theory.

Finding that the vertical theory did not accord with the results of actual observations, certain Belgian engineers adopted the view that the break takes place at right angles to the stratification, and named it the Normal Theory.

The normal theory is set forth in great detail in an elaborate memoir presented to the Municipal Council of Liége in the year 1871[1] by M. Gustave Dumont. The following is a short account of the events which led to M. Dumont's appointment to investigate the question, as given by himself:—

On September 15, 1825, the water suddenly disappeared from the wells belonging to the houses in the faubourgs Vivegnis and St. Leonard, and in the street Hors-Chateau, in the town of Liége; an old pit shaft, named Bure de la Vigne, situate near the fortifications, that had been abandoned and filled up forty years previously, fell in; and a considerable subsidence of the surface took place near the zinc works in the faubourg St. Leonard. At the same instant the workings of a colliery, named la Plomterie, were inundated by the water from the old workings of the Bure de la Vigne; and the natural inference was that the withdrawal of the water from the workings of the latter colliery was the proximate cause of the subsidence.

About this time many applications had been made for concessions to work the seams of coal underlying a large part of the lands belonging to the town, but the Municipal Council, being alarmed for the safety of the dwelling-houses and of the wells which supplied them with water, offered a strenuous opposition to every proposal of the kind. In spite of this opposition, however, a Commission was appointed to inquire into the matter on January 11, 1827. On March 5 of the same year the Commission issued its report, which contained the opinion that if no coal were worked nearer to the surface, or to any old workings, than 100 metres—measured vertically upwards—the solid crust thus preserved would be amply sufficient to guarantee the safety of both the houses and the wells. In the year 1830, the Belgian Revolution took place and nothing worthy of note in regard to the working of coal was done until 1839, when a second Commission was appointed. This Commission was requested to give replies to the three following questions:—

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[1] *Des Affaisements du Sol, produits par l'Exploitation Houillère* : 1871.

1. Would it be possible to work the coal in one or in several mines under the town of Liége without exposing the houses and their inhabitants to the dangers and inconveniences that had been pointed out by the Municipal Council in the year 1829?

2. If the reply to this question is in the affirmative, could the workings be carried on with regularity and profit by several companies at the same time, if the area were divided amongst them?

3. Under what conditions ought the workings to be carried on, either by one or by several companies?

Five members of the Commission expressed the opinion that the workings contemplated would not produce any serious subsidence; but two dissented from this view and issued a separate report. In answer to the second and third questions the majority replied as follows:—

(*a*) It would be preferable to divide the area amongst the various applicants.

(*b*) It should be stipulated, however, that no workings be carried on nearer to the surface than 200 metres or nearer to old workings than 100 metres measured vertically upwards.

The concessions were accordingly granted to the applicants, and extensions of area were conceded to them from time to time afterwards. The stipulation to leave a solid crust between the seams worked and the surface or the old workings, as the case might be, was not insisted on in every case; and even in those cases in which it had been made compulsory in the first place it was subsequently modified. For instance, in the case of Paradise Colliery, two royal decrees, dated respectively June 22, 1854, and April 29, 1861, were issued, the first granting permission to work the coal to within 150 metres of the surface on the right bank of the Meuse, the second to work the coal up to the same level on the left bank.

As the workings of the collieries began to approach the suburbs towards the year 1857, numerous movements of the surface affecting the houses, the water pipes, and the paving of the streets, began to attract the attention of the municipal authorities, and on June 12 of that year they appointed M. Dumont to report to them on the subject. But in the month of September following, more serious movements were observed in the neighbourhood of Paradise Chapel, and a Special Commission was appointed on March 31, 1858, as the question then appeared to involve the future well-being of the town itself. The report of this Commission was presented on July 2, 1859. In concluding, the Commission sum up as follows:—

> We are of opinion that the alarm which has exercised the minds of both the owners of the mines and of the surface, in consequence of the incidents that have happened in connection with the workings of Paradise Colliery ought not to lead to the introduction of any new preventive measure. . . . The Commission declares by a majority of six voices against one, that none of the new facts observed since 1839 are of such a nature as to require any

modification of the rules which have guided the administration up to the present time.

This authoritative pronouncement had the effect of lulling the apprehensions of the public, and M. Dumont, feeling that his services were not then urgently required, allowed the matter to slumber for a number of years. But in the year 1869, a serious subsidence having taken place in the district of Avroy-Louvrex-Guillemins, which damaged and compromised the safety of many of the houses belonging to the rich and powerful, the Municipal Council with renewed solicitude immediately called upon M. Dumont to proceed with his investigations and draw up his report without loss of time.

M. Dumont's report occupies 331 pages of a quarto volume, and contains a table giving upwards of a thousand levels at various points in the town. It is also accompanied by an atlas consisting of 25 plates. Unfortunately for the present purpose the question which he attempted to solve was complicated by the presence of old workings and by the existence of the workings of several mines all within a comparatively small area. He gives his unqualified support to the Theory of the Normal and endeavours to prove it by means of the facts at his disposal. He proves conclusively that in cases in which the seams were inclined the disturbance of the surface took place towards the dip of the seams, but his contention that it took place along lines normal to the dip is not altogether convincing, for the reasons given above. It is therefore impossible to reproduce any of his plans or sections without leaving the question which they are intended to elucidate still surrounded with a certain degree of obscurity, and on this account they have been omitted from this Paper.

The subject was again carefully investigated by M. Fayol, Director of the Commentry and Montvicq Mines in France, and the results communicated in a paper[1] to the Société de l'Industrie Minérale.

M. Fayol followed two distinct methods in endeavouring to arrive at such conclusions as the nature of the case might warrant: he instituted a series of experiments on a small scale in which he produced stratified beds artificially, and then partially withdrew the support from them so as to represent the effects of excavations; he also instituted a series of observations of the actual effects produced by the workings in mines, and for this purpose he took levels from time to time across the ground above and near the excavations. As M. Fayol's observations were made with the object of eliciting the laws which govern subsidence in Coal Measure ground, the cases which he observed were, as might be expected, not complicated in any way. The writer has therefore no hesitation in putting the results of the most important observations before the Institute.

M. Fayol's paper commences by reciting some of the contradictory opinions that have been expressed from time to time regarding this subject as follows:—

(*a*) *As to the extension of the movements upwards.*

1. The movements extend up to the surface whatever may be the depth of the workings below it.

2. The surface is not affected by the movements when the depth exceeds a certain amount.

(*b*) *As to the amplitude of the movements.*

1. The subsidence is propagated to the surface without sensible diminution.

2. The movements become more and more feeble as they extend upwards.

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[1] *Bulletin de la Société de l'Industrie Minérale*, tome xiv., p. 805. (1885.)

(c) *As to the relative position of the subsidence of the surface and the excavation below ground.*

1. The subsidence always takes place vertically above the excavation.

2. The subsidence of the surface is limited by certain lines drawn from the perimeter of the excavation and perpendicular to the beds.

3. The subsidence cannot be referred to the excavation, either by vertical lines, or by lines normal, that is at right angles to the beds, but only by lines which are drawn at an angle of 45°, the angle of talus, or repose, of the ground, or some other similar angle.

(d) *As to the effects of stowing or gobbing.*

1. The use of stowing effectually protects the surface.

2. Stowing simply diminishes the amount of subsidence.

3. The ground sinks much further when stowing is employed than when it is not.

It is thus evident that opinions are greatly divided; these differences are however more apparent than real; they are the result of generalising from single facts which are only particular cases of the following rule:—

The movements of the ground are limited by a kind of dome which has for its base the area of the excavation; their amplitude diminishes by degrees as they extend further away from the centre of that area.

Such is the conclusion to which M. Fayol was conducted by long-continued observations, supported and confirmed by many experiments. When he believed he had arrived at an understanding of the true law of these phenomena, he sought for an experimental verification of it which might permit those movements to be observed whose effects can only be seen at the surface or in the workings of mines. He instituted some simple experiments, which he thinks are conclusive, and they have at any rate the merit of being easily reproduced.

M. Fayol's rule agrees with all the facts observed: absence of subsidence, more or less important subsidences, movements limited to the vertical above the perimeter of the excavation, those limited to the normal or to other inclinations, and so on. It has the disadvantage of being indefinite; but in a question which embraces so many elements, many of which are unknown or not well known, such as the nature of the rocks, the thickness of the beds, geological accidents, the action of water, &c., we cannot hope to arrive at absolutely accurate formulæ; we shall have already accomplished much when we get to know very nearly the true form, the direction and the relative amplitude of the subsidences, and are in a position to combat false ideas successfully.

After a general understanding of the character of the movements has been arrived at and many observations have been made, it will probably be possible to foresee by analogy the absolute proportions of the movements relatively to those of the excavations.

In the first place, however, it will be instructive to consider certain phenomena which play an important part in the question or facilitate its explanation; thereafter certain experiments and observations will be described, and finally some conclusions will be drawn from this study which appear to be justified by the facts.

I.—Flexion of Beams fixed at both ends.

It is known that a beam or girder fixed at its two ends will bend to a certain extent under the influence of its own weight, and that the degree of curvature increases with the distance between the points of support. If two similar beams are superposed, the lower one bends more and the upper one less than if there were only one. If the number of pieces is increased, the lowest beam bends more and more up to a certain extent, and thereafter it retains the same curvature whatever may be the number of pieces added.

The lowest beam always bends most; the curvature becomes less and less in ascending, and at a certain height the beams retain their horizontal position. The limit of the bent portions of the superposed beams is itself a curve which sets out from the points of support of the lowest beam and rises until it reaches the highest beam which is not curved.

The form of this limiting curve depends on the nature and dimensions of the beams and the distance between the points of support. Following are some examples:—

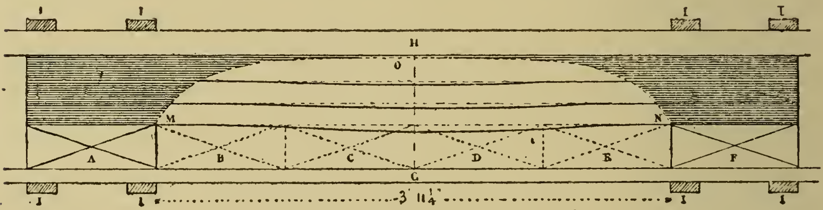

Fig. 1.

Experiment No. 1.—A certain number of bars of iron each 50 millimetres (2 in.) in width by 5 millimetres (0·2 in.) thick were placed on their flat sides horizontally one above the other upon blocks of wood A, B, C, D, E, F. The blocks of wood rested on a cast-iron table G, planed quite smooth on the surface. A strong iron straight-edge H was placed over the uppermost bar, and the whole assemblage was then tightly bound down to the table by means of glands I, I, I, I and bolts.

Thereafter the wooden blocks B, C, D, E were drawn out, leaving a space of 1·2 metre (4 ft.) unsupported, and the curvature of the iron bars was observed.

Fig. 1 shows this curvature.

For the sake of greater clearness only a few of the bent pieces are shown in the figure, and the scale of curvature has been doubled.

With a width of 1·2 metre (4 ft.) it was found that the lowest bar was bent downwards 5 mm. (0·2 in.), the tenth 3¼ mm. (0·128 in.), the twentieth 1¾ mm. (·069 in.), and the thirtieth not at all.

The limit of curvature is the flat arch MON.

Experiment No. 2.—A single bar of iron 50 mm. (2 in.) by 5 mm. (0·2 in.) held between points 1·2 metre (4 ft.), apart bent down to a distance of 2 mm. (·078 in.).

With two bars, one above the other, the bending of the

lower bar was	2½ mm.
4 bars	2¾ ,,
8 ,, ...	3 ,,
16 ,, ...	4¾ ,,
32 ,, ...	5 ,,
40 ,, ...	5 ,,

At the thirtieth bar counting upwards the bending ceased.

Experiment No. 3.—Replacing the bars of iron by pieces of flat winding ropes made of aloes 240 mm. (10 in.) wide 40 mm. (1½ in.) thick, the amount of bending was greater and the limiting curve higher.

The lowest piece of rope bent 35 mm. (1·38 ins.), the 5th 15 mm. (0·6 in.), the 10th 5 mm. (0·3 in.), and the 12th remained horizontal.

Experiment No. 4.—With belts made of canvas and india rubber, width 120 mm. (4·7 in.), thickness 10 mm. (0·4 in.) the bending is still greater than in the last case (Fig. 3).

50 mm. (1·9 in.) for the lowest band.
37 mm. (1·45 in.) ,, 25th ,,

In consequence of not having a sufficient number of bands it was impossible in this case to find out at what height they became horizontal—with a width of 1·2 metre (4 ft.)—between the supports. In reducing the width to 0·3 metre (13 in.), the bending of the lowest band was 9 mm. (0·4 in.) and the 25th was horizontal.

The curve of the limits of bending—that is to say, the limit of the zone of subsidence—is practically equal to the distance between the points of support in this case. With winding ropes it is about $\frac{1}{3}$rd of the same distance and with bars of iron about $\frac{1}{6}$th.

Wood gives similar results.

It will be seen further on that rocks manifest identical phenomena.

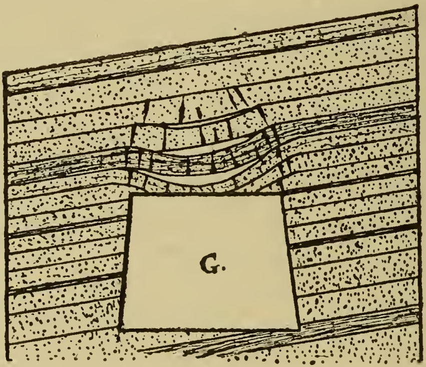

Fig. 2.

Attention may here be called to a case which can be constantly observed in collieries. The beds which form the roof of a gallery G are bent down and fractured. The curvature of the second bed is less than that of the first, that of the third is still less, that of the fourth hardly appreciable, and the fifth has not moved at all. The zone of subsidence is restricted within very narrow limits.

The decrease of the bending of superposed pieces appears to result from the circumstance that the lower part of each piece lengthens more than the upper part; a piece unable to assume the exact form of the one below it rests upon the latter, and the points of support thus approaching each other more and more in passing successively upwards finish by becoming one and the same.

MODE OF FRACTURE OF ROCKS.

It is generally thought that beams supported and weighted between their points of support break perpendicularly to their length—that is to say, in a vertical plane if the beams are horizontal. This is a mistake, and this mistake has given rise to the theory of the *normal*, which shall now be dealt with.

In reality the break takes place in an inclined plane leaning over the excavation.

EXPERIMENT No. 5.—M. Fayol fixed blocks of sandstone and shale with their flat sides horizontally—that is to say, in the same plane as their stratification—but in such a way as to leave about one half of their length free, or outside the appliances for fixing them. Then a gradually increasing pressure was applied without shock to the free part until it was broken off. Of ten blocks so treated, eight broke along an inclined plane sloping upwards and outwards (*a*), one in the plane of the normal (*b*), and one in a plane sloping inwards (*c*).

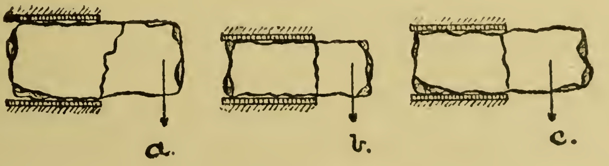

FIG. 3.

The break thus generally occurred in a plane leaning over the excavation.

Increase of Volume—Compressibility.

Swelling.—When rocks are broken into pieces their volume increases. This swelling, which is very variable according to the kind of rock and its physical condition, may be considerable. The following experiment affords some data upon this subject.

Experiment No. 6.—Certain rocks were reduced to dust or into grains of various sizes and their volumes were measured. The following table gives the results:—

Kind of Rocks	Volumes					
	of the solid rock	in the form of dust	in grains of 2 to 3 mm.	in grains of 10 to 13 mm.	in grains of 15 to 20 mm.	mixture of grains and dust
Clay	100	196	209	226	225	216
Shale	100	243	210	221	224	229
Sandstone . . .	100	219	214	211	210	214
Calcined Sandstone and Shale, half melted	100	245	240	217	220	218
Coal	100	207	224	199	223	202

This table shows that rocks are susceptible of considerable swelling and that the empty spaces between the fragments may be equal or even superior to the volume of the solid rock.

In breaking up, the rocks may take all the volumes intermediate between their original volume and that of their maximum swelling. Examples of this increase in bulk may be seen in the open quarries from which stowing is obtained for the Commentry mines, mostly situate above old workings. Great falls of stone much broken up are surmounted by beds full of fissures, and the latter in their turn support beds less and less affected. Excepting at these points the walls of the cuttings seen from a distance present the appearance of intact beds which have not undergone any movement; but when they are examined at close quarters fissures can be seen at intervals in the sandstone many of them being several centimetres wide, while in the shale there are many cracks close together. According to its nature coal behaves sometimes like sandstone, sometimes like shale, in this respect.

These rocks are seen in all possible states of disaggregation, from that of a fall to that of rock barely curved and hardly even cracked. The width of the cracks or fissures is generally in proportion to the amount of disturbance which the beds have undergone; it is almost *nil* in beds which have been subjected to only feeble movements; and it rarely surpasses 2 per cent. or 3 per cent. in those which have subsided but not fallen to pieces.

The mixture of sandstone and shale used for stowing as quarried and filled with the shovel (large and small mixed) has increased about 60 per cent. in volume.

Shrinkage.—We have seen that the movements of the ground produce a certain degree of swelling or increase of volume which may bear a proportion varying from 0 to 100 per cent. or even 150 per cent. relatively to the original volume.

We know also that rocks which have undergone an increase in volume can be compressed, and that all the more easily according as the increase has been greater; and that, on the other hand, their resistance to compression increases rapidly as their volume diminishes.

In connection with the question of subsidence, it is important to ascertain to what volume rocks which have undergone disaggregation to any particular extent from the effects of underground workings can be reduced by pressure.

The following experiment was made with this object :—

Experiment No. 7.—Certain rocks previously reduced to the form of dust (clay, shale, sandstone, coal) were subjected to pressures of 100, 200, 500, and 1,000 kilogrammes per square centimetre. These pressures correspond to depths of 500, 1,000, 2,500, and 5,000 metres under the surface.[1]

The compression was effected in small steel cylinders of 4 centimetres (1·57 in.) deep and 3·57 centimetres (1·4 in.) in diameter (10 square centimetres, 1·55 sq. in.) for pressures of 100 and 200 kilogrammes, and 1·6 centimetre in diameter (2 square centimetres) for pressures of 500 and 1,000 kilogrammes.

At the end of a few seconds the pressure had produced its full effect, and the substance had assumed the volume corresponding to the pressure.

Most of the substances, whether in grains or dust, became agglomerated under these high pressures, and some of them formed coherent cylinders.

The grains on the exterior are usually crushed, while those in the interior of the cylinder, even after being subjected to a pressure of 1,000 kilogrammes, are found to be intact.

Trials were made separately with dust, grains, and a mixture of grains and dust. The degree of subdivision did not materially modify the results. Following are the mean results obtained :—

---

[1] 1 kilogramme = 2·20462125 lbs. avoir.
1 square centimetre = 0·155006 sqr. in.
1 metre = 3·2809 feet.

	Volume of the compact rock	The rocks were previously pulverised or broken. Volume remaining after the pressures of			
		100 kil. per square centimetre	200 kil. per square centimetre	500 kil. per square centimetre	1,000 kil. per square centimetre
Clay	100	101	90	75	70
Shale	100	128	116	110	97
Sandstone . . .	100	136	125	120	105
Calcined Sandstone and Shale	100	141	130	119	109
Coal	100	130	125	118	109

Clay was reduced to its original volume by a pressure of less than 200 kilogrammes per square centimetre, shale by a pressure of over 500, while sandstone and coal retained an increased volume under a pressure of 1,000 kilogrammes. We may conclude from this—

1. That the ordinary stowing employed in mines of less than 1,000 metres deep, and consequently not subjected to a pressure of more than 250 kilogrammes, always retains a certain increased volume.

It is difficult to have any exact data regarding the shrinkage of stowing in mines, on account of the irregularity of the excavations and the proportion of empty spaces which remain unfilled in spite of the utmost care. The ordinary materials (shale and sandstone) which are employed, after having undergone an increase of volume amounting to 60 per cent., appear to undergo a shrinkage of about 30 per cent. in mines between 100 and 300 metres deep, leaving them with a volume of about 12 per cent. greater than that of the compact rock from which they were obtained.

The stowing is, besides, very unequally compressed; in some places it can be seen practically loose alongside other places where it has been crushed and solidified by the pressure.

2. That the cracks and fissures which have been produced by the movements of the ground above an excavation remain open either wholly or partly.

It would be necessary, in fact, to descend to a depth of 2,000 metres before the weight of the ground amounted to 500 kilogrammes per square centimetre.

The action of water is here left out of account, although it may play an important part in the shrinkage of the ground. In the presence of water the pressure is no longer necessary to fill up the voids and reduce the stowing to a great degree of density. Water may greatly modify the effects of the shrinkage as considered in this place.

II.—Experiments concerning the Movements of the Ground.

The object of these experiments was to reproduce, on a small scale, the movements of the ground caused by the workings in mines, and that in such a manner as to be able to observe their progress and note their peculiarities.

After several trials the following method was adopted:

Artificial beds of earth, sand, clay, plaster of Paris, or other substances were laid down in a wooden box, one of whose sides was made of glass.

The box may be made of any desired dimensions. The one which M. Fayol employed most frequently was 0·80 m. (32 in.) long, 0·30 m. (11·8 in.) wide, and 0·50 m. (1 ft. 8 in.) high.

The first bed was laid down in the bottom of the box; upon the first bed a second was placed either of the same or a different kind, and thereafter successive beds were laid down one after the other until the box was filled. The thickness of the individual beds varied from 1 millimetre (·004 in.) to several centimetres (1 or 2 in.)

The glass front permitted the stratification of the beds to be seen. In order to note the movements small pieces of paper 2 centimetres (0·78 in.) long, 1 centimetre (0·4 in.) wide, were laid down between the planes of stratification with their edges only visible. Thereafter marks were made on the glass with ink immediately in front of each scrap of paper. The marks on the glass constituted fixed points, which enabled the slightest movements of the ground to be observed.

To simulate a working underground, and produce the movements of the strata overlying it, the following plan was followed:

Before commencing to lay down the artificial beds, small laths of wood of equal thickness, several centimetres wide and as long as the width of the box, were laid down side by side in the bottom. The laths actually employed were 1 to 20 millimetres (·04 to ·80 in.) thick, and either one or several beds of laths were superposed upon each other.

The artificial strata were laid down upon these beds of laths.

In drawing out the laths the excavations were formed, and the movements of the ground produced.

A few hours are sufficient to make preparations for and carry out an experiment.

In order to produce beds with different inclinations, the box, already filled with horizontal beds, can be tipped up more or less at one end; or, otherwise, the beds can be laid down at the desired inclination from the first.

The experiments can be varied to any extent by modifying the dimensions of the box, the laths, the beds, the nature of the materials of which they consist, the inclination of the beds, and all the other details.[1]

Experiment No. 8.—*Excavations under Horizontal Beds.*—Horizontal beds of dry sand, wet sand, and plaster of Paris were laid down successively upon three rows of laths, each lath being 1 centimetre (0·4 in.) thick. Marks were made on the glass which exactly covered the edges of the morsels of paper placed between the beds. The laths were then withdrawn in the order indicated by the numbers.

Fig. 4 represents the movements produced by the withdrawal of the upper or first row of laths; Fig. 5 the movements produced by withdrawing the second; and Fig. 6 those of the third.

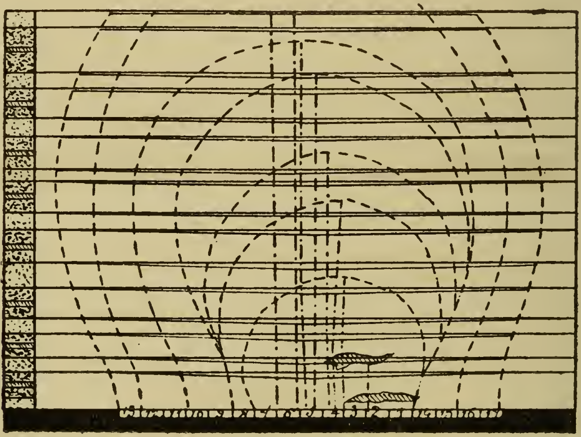

Fig. 4.

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[1] Plaster of Paris and sand are especially suitable for these experiments.

Beds of solid plaster of Paris can be easily formed by spreading out the plaster of Paris, in the form of powder, upon a damp bed of clay or sand, and covering it with another damp bed.

With a box of the small dimensions mentioned, beds of damp sand are already sufficiently cohesive for the purpose of the experiment.

To facilitate the drawing-out of the laths, the upper row is covered with pieces of thin cloth, which enable them to slip out more easily and prevent the stuff which constitutes the bed above them from being drawn out at the same time.

The zones of subsidence of the first row, of the second, and of the third, are distinguishable from each other.

The hatched surfaces represent the empty spaces produced during the operation.

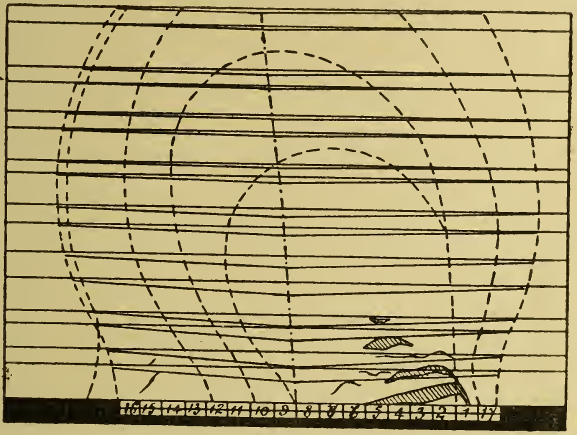


Fig. 5.

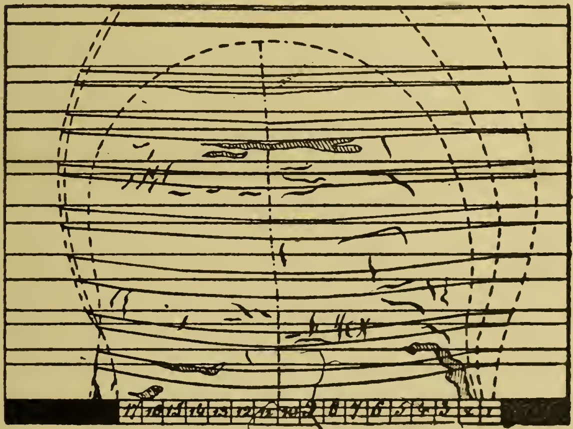


Fig. 6.

Withdrawal of the second slice, or row of laths (Fig. 5).—The second row was withdrawn in the order of the numbers. In this way the height of the excavation was doubled.

Withdrawal of the third slice, or row of laths (Fig. 6).—The withdrawal of the third slice increases the disturbances produced by the withdrawal of the two previous slices. The fissures in the beds and the empty spaces between the strata are increased in number, and some are opened more than before, while others are closed.

EXPERIMENT No. 9.—*Excavations under Inclined Beds.*—These experiments were undertaken with the object of showing the mode of formation of the zone of subsidence and the general direction of its axis in inclined beds.

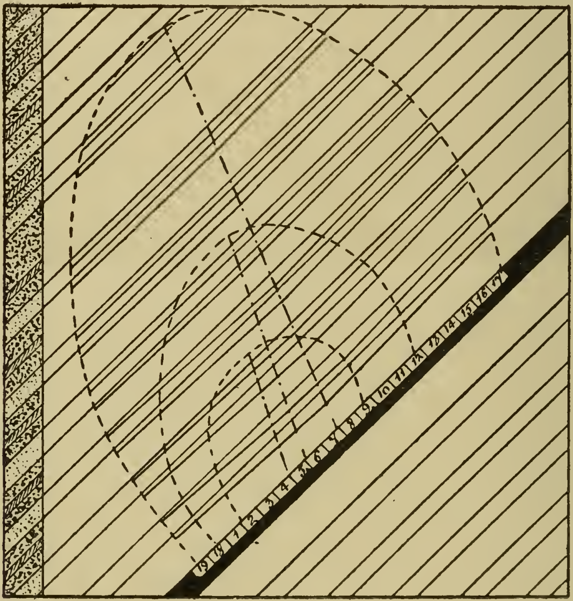


FIG. 7.

It is seen that the thick lines which represent the axes of the domes are no longer vertical.

The surface level is not reached by the dome in any of these three cases.

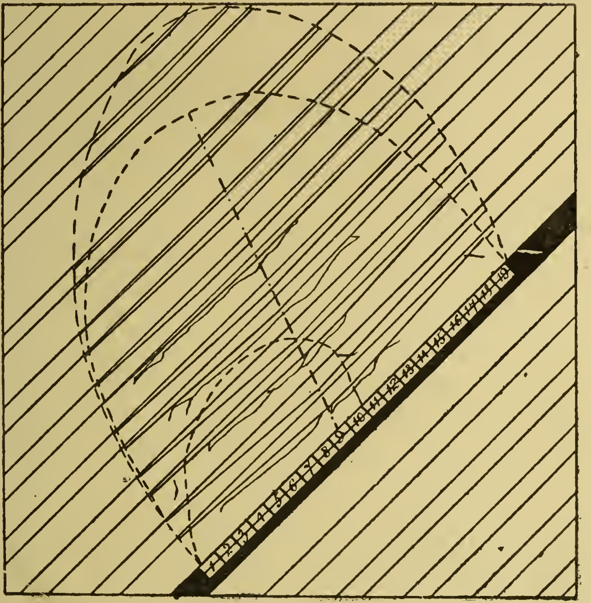


FIG. 8.

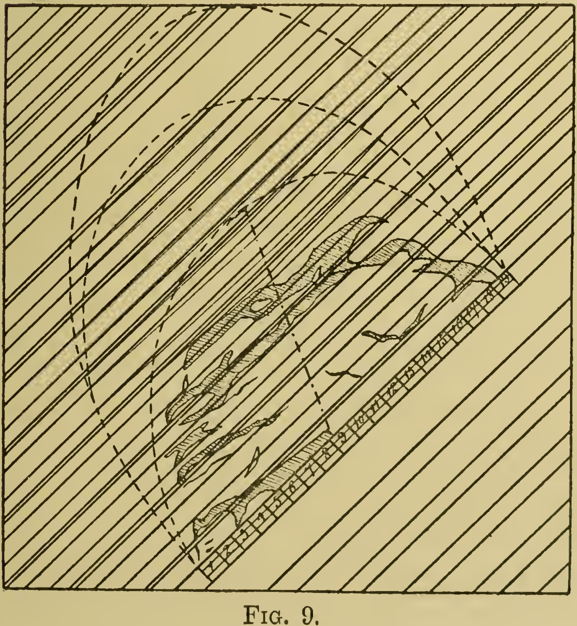


FIG. 9.

OBSERVATIONS.

OBSERVATION No. 2.—*Subsidence of the Surface above a Shallow Working of Small Area.*

The thickness of the seam was 1·3 metres (4 ft. 3 in.) It was almost horizontal.

The coal was taken out by successive chambers without stowing, excepting only the beds of rubbish found in the seam which were left in the workings. The roof was supported on timber.

At the moment when the workings attained the dimensions shown (350 sq. m.) a subsidence took place extending to the surface.

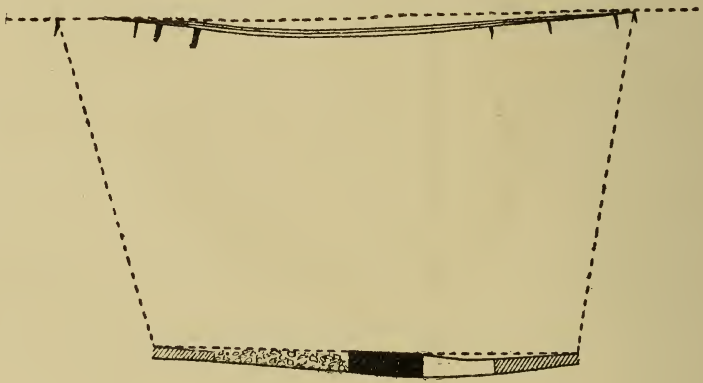


FIG. 10.
Section on the line A B of Fig. 11.

The surface was 18 metres (59 ft.) above the working. The ground consisted of sandstone and some thin beds of shale for 9 metres (29 ft. 6 in.), and an equal thickness of made ground above.

Underground there had been no previous movement during the working of the coal, which extended over a period of three months. At the expiry of that time noises began to be heard, and these were accompanied by a breaking-up of the superincumbent mass. These noises went on increasing. Four hours later the roof had sunk visibly—the timbers were broken throughout the whole of the excavation, and a sudden collapse took place, accompanied with much noise.

At the moment the collapse took place in the workings the surface sank suddenly, a hollow was formed 30 metres (98·4 ft.) in diameter and 50 centimetres (1·64 ft.) deep, and cracks were seen round about the hollow.

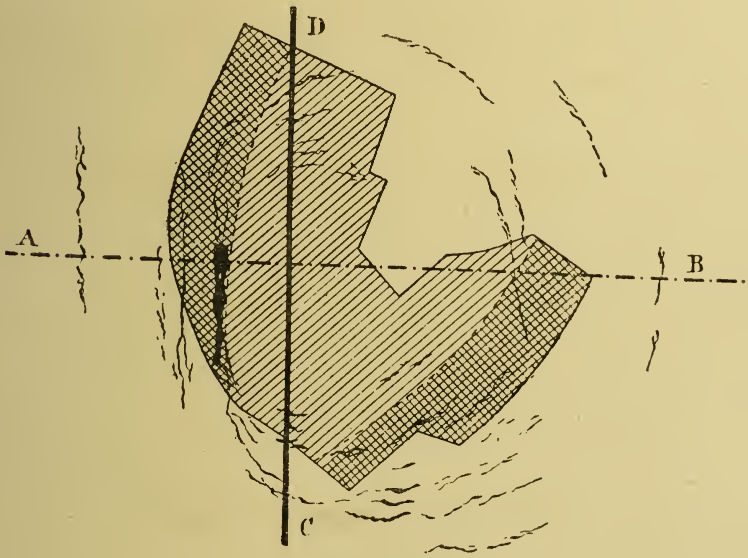


Fig. 11.

An uncovered water conduit, which had been horizontal before the subsidence, was curved in the same way as the surface. On the edges of the hollow some of the tubes became separated from each other, but in the middle the pipes were pushed into each other to the same extent.

The movement was very rapid. In three minutes the subsidence amounted to 0 50 m. (1·64 ft.), and during the succeeding twenty-four hours it increased only by 0·21 m. (0·68 ft.) more, and later there was no further sensible increase.

The following features should be remarked :—

1. The subsidence is in the form of a hollow.

2. The area of the subsidence is greater than that of the workings.

3. The irregularity, the discontinuity, and the multiplicity of the cracks, which follow the contour of the subsidence in a manner which might be on the whole considered regular.

4. The absence of cracks in the middle of the hollow.

5. The inclination of the cracks, which trend towards the centre of curvature.

This observation may be taken as an example intermediate between the experimental results and the observation on a large scale which follows :—

OBSERVATION No. 3.—*Working by Horizontal Slices with complete Stowing in a Seam* 14 *metres* (46 *ft.*) *thick with an inclination of* 34 *degrees.*

The slices are 2·50 m. (8ft. 2in.) high. The stowing consists of sandstone and shale obtained from a quarry on the surface. Fig. 12 represents a section on the line of greatest dip. Two slices have been worked. The surface has sunk in a hollow. Above the hollow are shown curved lines giving on an exaggerated scale the position of the surface at various dates, corresponding to the workings underground at the same dates. Fig. 14 is a plan on the level of the first slice. The hatching in different directions shows the parts of the slice worked out during certain periods.

Fig. 13 is a section on the line NM of Fig. 12, which is not vertical.

This line has been drawn through the points where the subsidence is greatest, so as to show the influence of the workings on the surface.

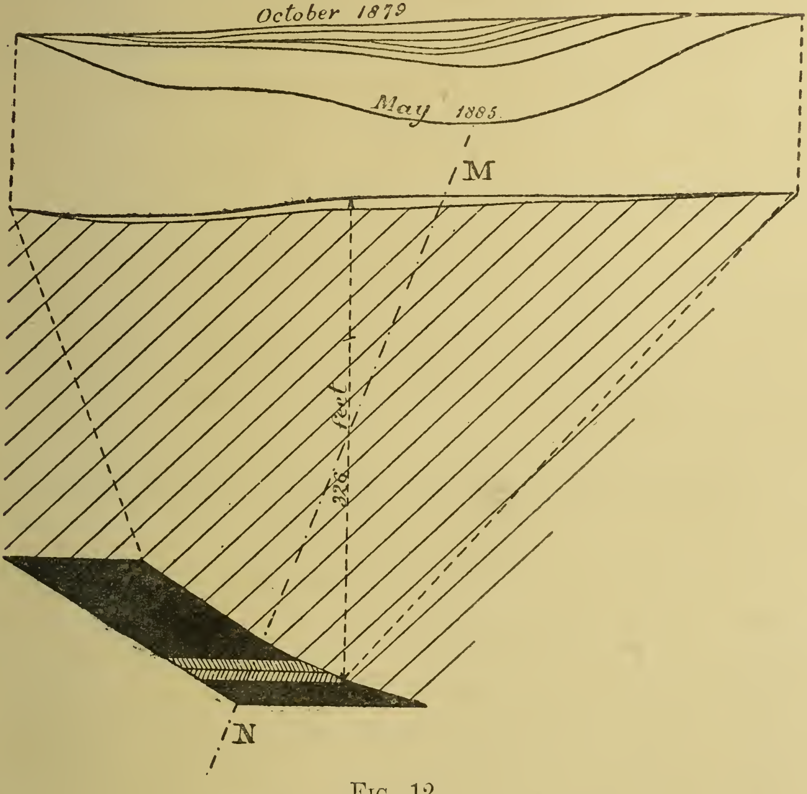


FIG. 12.
Section on the line C D of Fig. 11.

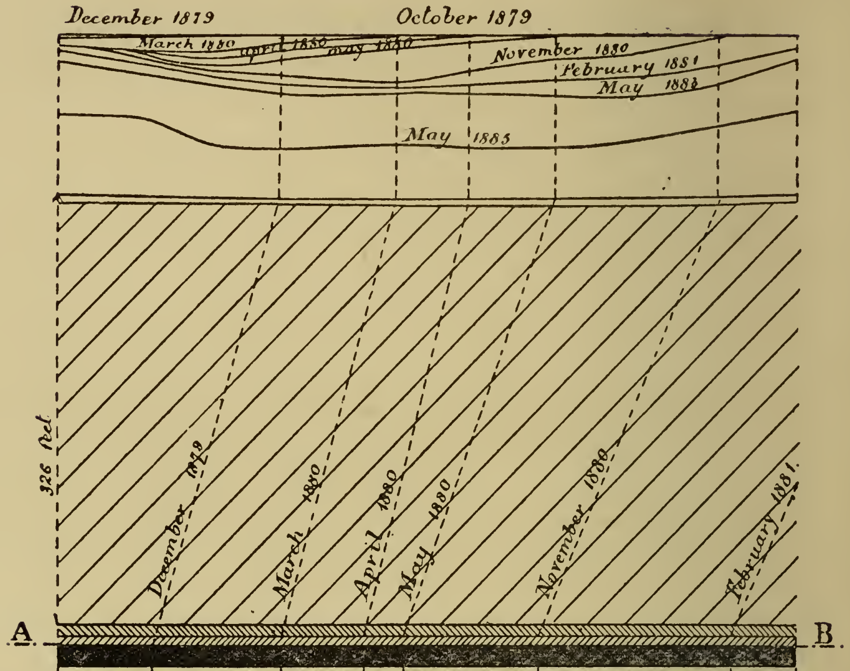
The curved lines above (in this case also exaggerated for the heights) indicate the successive movements of the ground during the working of the first slice, and also the same movements after the removal of the second slice.

These figures show that—

1. During the working-out of the first slice the sinking

FIG. 13.

Section on the line M N of Fig. 12.



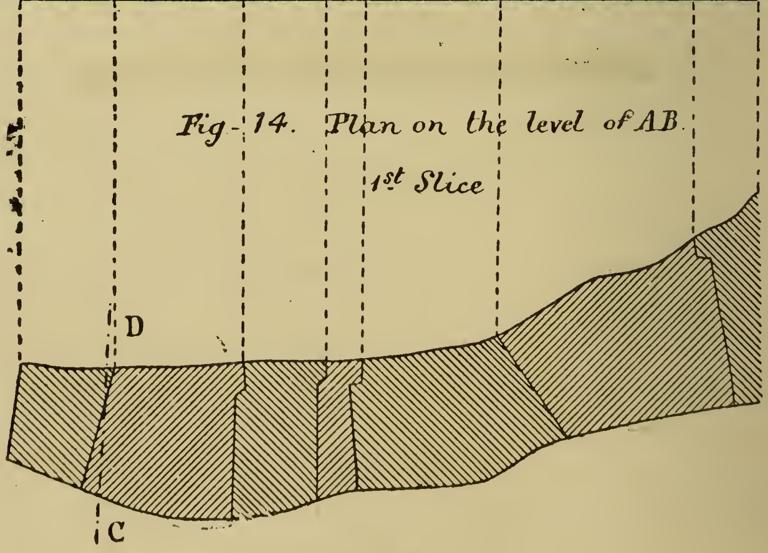


FIG. 14.

proceeded gradually. It increased considerably when the second slice was taken out.

2. The movements of the ground produced hollows.

3. The area of the subsidence at the surface is about four times as large as the area worked in the seam.

4. The greatest amount of subsidence is 1·03 m. (3 ft. 4½ in.), which is about one-fifth of the height excavated.

Figs. 13 and 14 show how the zones of subsidence developed themselves above those of the workings.

OBSERVATION No. 4.—*Working of an Irregular Mass of Coal.*

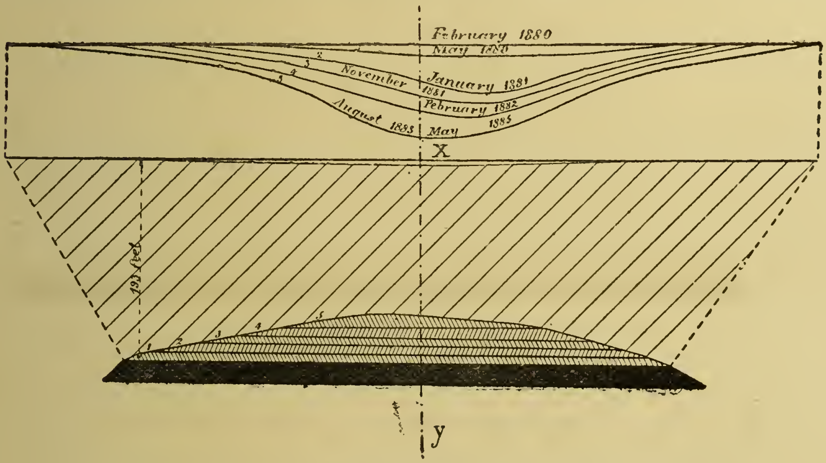


FIG. 15.
Section on the line H K of Fig. 16.

The slices which were stowed were taken in ascending order, as indicated by the numbers of the figures. It is seen that—

1. The subsidence gradually increased in depth and extent in proportion as new slices were taken, although the last slices were smaller in area than the first.

2. The area of subsidence is much greater than the area of the excavation.

3. The greatest depth of the subsidence is one-tenth that of the height of the working.

The subsidence cannot be referred to the working either by a normal to the inclination or by a vertical.

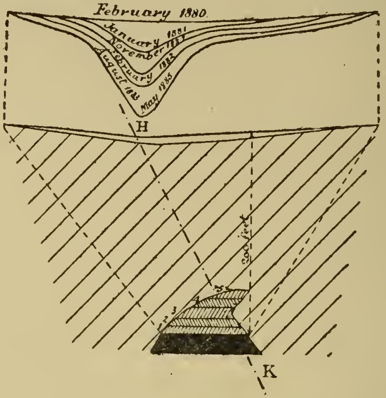


FIG. 16.
Section on the line X Y of Fig. 15.

OBSERVATION NO. 5.—*Movements of the Surface caused by working with Stowing the last parts of a Thin Seam already worked over a large area.*

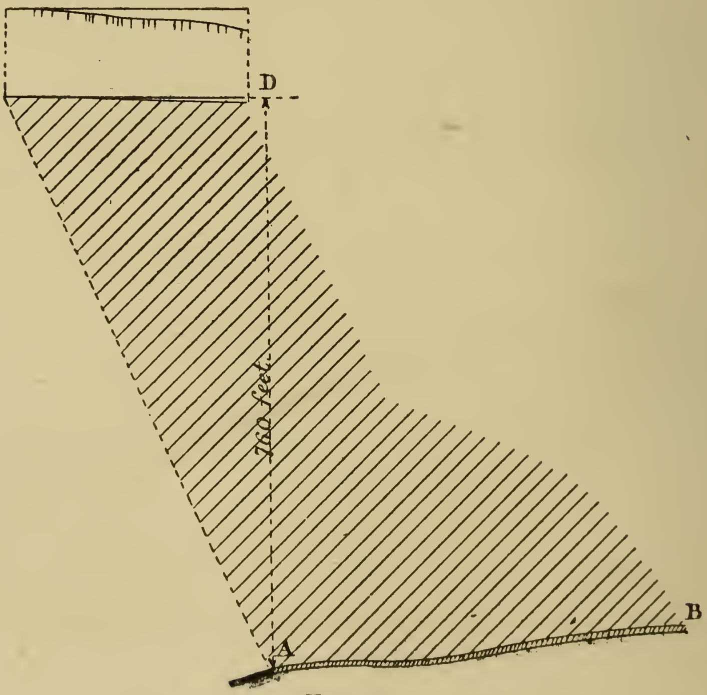


FIG. 17.

The shading AB shows where the seam has been already worked. Its thickness is 2 m. to 2·50 m. (6 ft. 8 in. to 8 ft. 4 in.). Its depth at A is 228 m. (748 ft.) below the surface. The subsidence at CD is rendered visible by cracks in masonry.

note

The amount of subsidence at D is 0·44 m. (1 ft. 5 in.).

It shows how this movement enters into the theory of zones of subsidence. Neither verticals nor normals can connect the extreme points of the working and of the subsidence.

Observation No. 6.—*Working without Stowing of a limited area in a Seam 2 m. (6 ft. 8 in.) thick.*

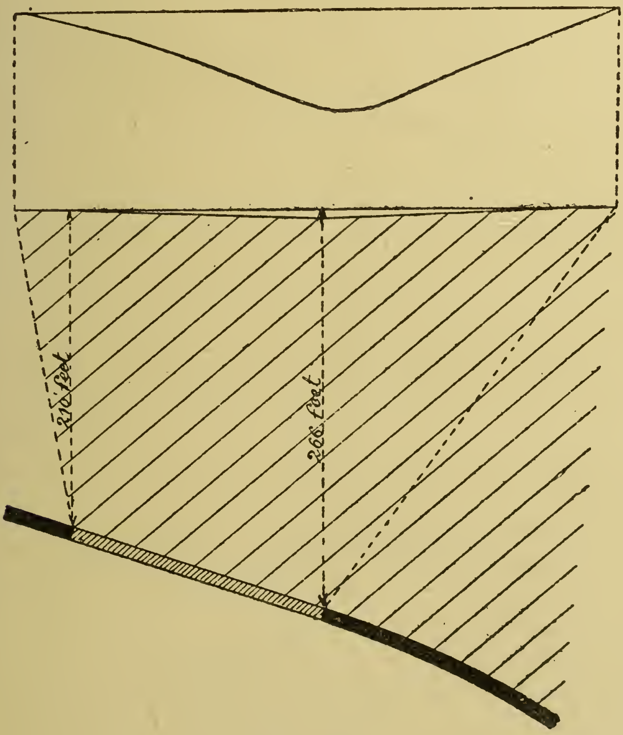


Fig. 18.

The surface shows a subsidence of twice the area of the working, which is not referable either to the normal or the vertical.

OBSERVATION No. 7.—*Working without Stowing of a Seam 2·25 m (7 ft. 6 in.) thick. Simultaneous and gradual progress of the workings and of the movements of the surface.*

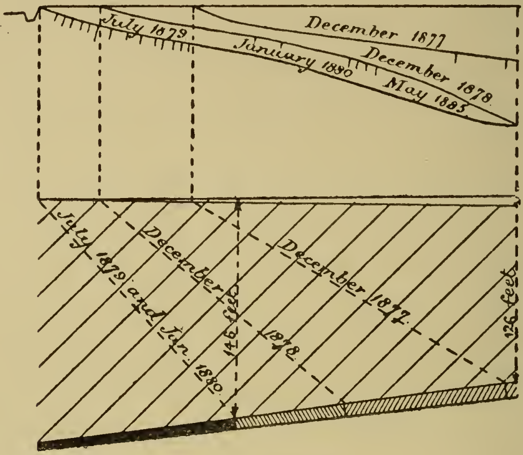


FIG. 19.

The depth of the seam is 40 metres (131 ft.).

The subsidence of the surface shows itself in front of the working face and beyond the normal to the dip.

The crevices are seen to open at the edges of the subsidence and to close up afterwards when they are left behind.

OBSERVATION No 9.—*A Pillar left to protect a Shaft.*

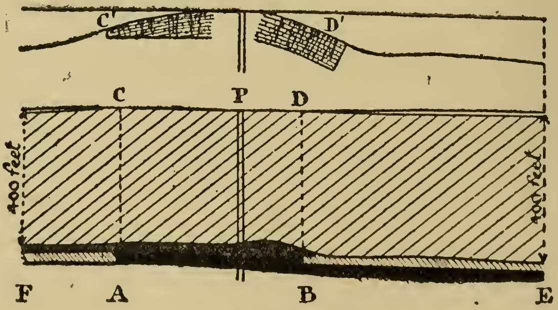


FIG. 20.

The pillar AB was left to protect the pit P and the erections which covered the surface CD.

The seam is 18 to 20 metres (60 to 65 ft.) thick. On the two sides BE and AF a thickness of 8 metres (26 ft.) had been worked. The surface subsided on both sides, and the movements were felt right up to the middle of the area CD.

The buildings with regular courses of masonry, which were originally horizontal, assumed the curvature of CD, and the curvature of the surface is similar to that of the walls. It is equally pronounced, but regular, and without projection.

The same results are observed in the case of all pillars left in the middle of workings—either for the purpose of preserving pits or for any other object. Whatever be the inclination and thickness of the seam, the subsidence takes place in every direction by regular curves round about the pillar, and extends even to its middle in many cases.

OBSERVATION NO. 10.—*Workings which have not produced any Subsidence of the Surface.*

As a rule the subsidences do not show at the surface, unless the area worked has reached a certain magnitude, and this magnitude must be all the greater in proportion as the seam is deeper and thinner.

If the area worked is small, or if, although large, it is interrupted by sufficient pillars, the surface is not affected.

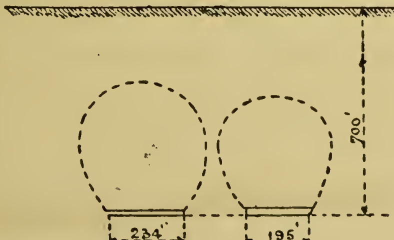


FIG. 21.

Fig. 21 shows the arrangement of workings of large area in lenticular masses of 2 to 6 metres (6·56 to 19·68 ft.) thick which have not produced subsidence of the surface from a depth of 210 metres (688·8 ft.).

Observation No. 11.—*Effect of taking out a Pillar between two Areas of Workings.*

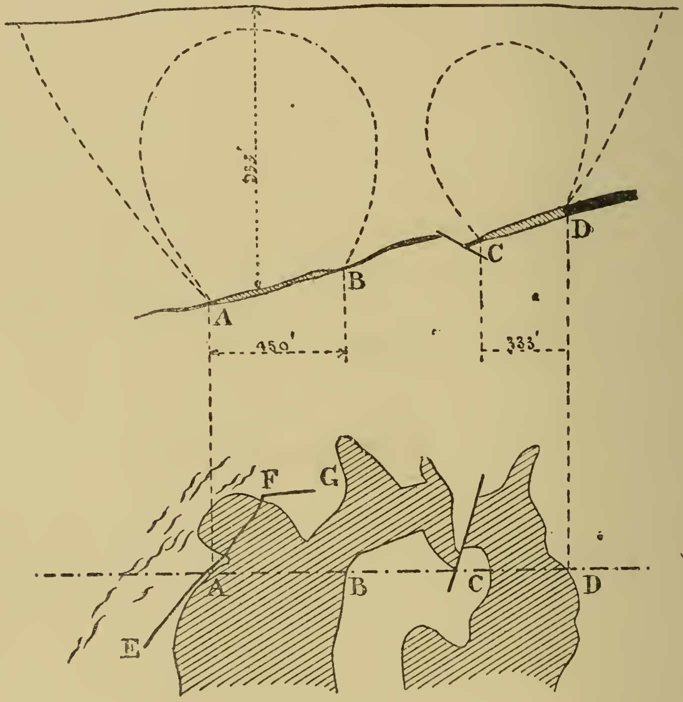


Fig. 22.

The areas AB and CD were worked with stowing. The seam is from 2 to 6 metres (6·56 to 19·68 ft.) thick. The workings were between 200 and 300 metres (656 and 984 ft.) deep below the surface.

The surface did not move until after two-thirds of the pillar BC had been taken out, and then the crevice EFG was produced along with other smaller crevices.

This example shows that isolated areas of workings, although somewhat extensive, do not produce subsidences at the surface, and confirms the previous one in this respect. It shows also that the removal of a small pillar from the midst of old workings may produce important effects at great distances.

The crevice EF, 180 metres long, is nearly straight, although the workings are sinuous.

Observation No. 12.—*Fractures of the Ground, Crevices, Cracks.*

It is seen from the figures already referred to that the fissures generally show themselves round about the edges of the subsidence. The hollow produced by the subsidence is usually concave in the centre and convex on its edges. The

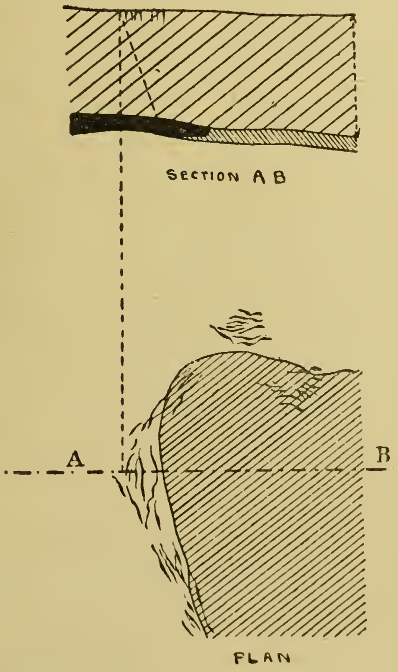


Fig. 23.

convex part has been stretched out, and for this reason the cracks are produced in it.

When the subsidence moves forward the first cracks close up and new cracks are formed in the same relative position to the convex curve.

The cracks are generally arranged in lines which are numerous, discontinuous, sinuous, and irregular. The diagram shows this clearly. It represents the crevices which existed on the edge of a large area of workings in the thick seam at Commentry at the moment the workings were in the position shown. Very few, if any, crevices are found within the subsided area at some distance from its edge.

Crevices are frequently very large, and this is no doubt due to two crevices having approached each other and thereby determined the fall of a block of ground between them.

Conclusions.

M. Fayol draws a number of conclusions from his observations and experiments, but this Paper would exceed moderate limits were it made to include the whole number. For this reason the writer proposes to confine his remarks to a few of the more important.

Influence of stowing.—If excavations were stowed in a thoroughly tight and efficient manner with incompressible materials there would be no subsidence. But ordinary stowing is not done under these conditions. The materials employed are all more or less compressible and the excavations are never perfectly filled up.

When the roof settles down the stowing resists feebly at first, the resistance rapidly increases and finally it arrests the downward movement.

Following are some examples taken from the Commentry mines:—

(*a*) Certain seams of 1 to 2 metres (3·28 to 6·56 ft.) thick, in which the workings were kept open with great difficulty so long as they were worked without stowing, required hardly any timber after stowing was resorted to.

(*b*) The timber was very expensive and the roof in a continual state of movement near to and at the faces in one district in the thick seam of Commentry in which clayey materials were employed for stowing. Calcined shale was substituted for the clayey materials and immediately the working places became firm, the roof ceased to subside to the same extent as formerly, and the cost of timber became much less than before.

Amplitude of the Subsidence.—The amplitude of the subsidence diminishes in proportion as the workings are deeper below the surface. The diminution is proportional to the increase of depth.

Above the workings of a seam 1 metre (3·28 ft.) in which stowing is not employed, subsidence is not appreciable at 200 metres. If the same seam were worked with stowing, the subsidence would cease at 80 metres above it. If the width of the excavation were reduced to 40 metres *with or without stowing* the zone of subsidence would not extend upwards to a greater height than 80 metres.

In working a bed 4 metres thick the movements of the ground above the workings would be as follows:—

In an indefinitely large area of workings:	
without stowing	800 metres
with stowing (which shrinks 40 per cent.).	320 ,,
Area worked restricted to 50 metres wide:	
without stowing	200 metres
with stowing	100 ,,

These figures have no pretence to absolute exactness, but they appear to be applicable to cases in which beds of sandstone constitute the principal part of the overlying strata, and the inclination does not exceed 40 degrees.

Means employed to protect the Surface.—Subsidence could be prevented by employing incompressible stowing[1] and carefully filling up all the voids. This process would however be too costly.

It is easier to accomplish the same object by leaving pillars in the workings. This process is known to be efficacious and is the one most generally employed.

A knowledge of the laws which govern the movements of the ground will greatly facilitate the determination of the best course to be followed in any given case for the protection of any particular part of the surface.

The meshes of the network consisting of pillars with working places between them should be made smaller as the workings are shallower. As the depth becomes greater the size of the meshes can be enlarged and the dimensions of the areas worked can be increased relatively to the sizes of the pillars that are abandoned, regard being had to the height and width of the zones of subsidence so that the various zones may be kept distinct from each other.

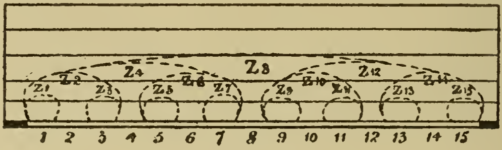


FIG. 24.

This general rule is susceptible of many combinations according to the thickness, the inclination, the number and the depth of the seams worked.

If the excavation is of small dimensions the subsidences which take place above them are restricted in size and become enlarged both in width and height as the excavation increases in area.

---

[1] When the use of stowing is referred to by continental writers, the materials employed are understood to be brought from the surface.

If each of the pillars 1, 3, 5, 7 is taken out singly, zones of subsidence similar to Z_1, Z_3, Z_5, Z_7 would be produced; but when pillar 2 is taken out the line of roof subsides on to the floor, and the zone of subsidence rises to Z_2. The same thing happens when No. 6 pillar is taken out, and if No. 4 pillar is taken out the space comprised between the zones Z_2 and Z_6 is set in motion and determines the formation of the zone Z_4.

The same series of movements is produced during the working out of the pillars 9 to 15, taken in the same order.

But the zone of subsidence does not rise upwards indefinitely; at a certain distance towards the fortieth pillar, for example, the taking out of further pillars has no further influence upon the parts worked in the first place.

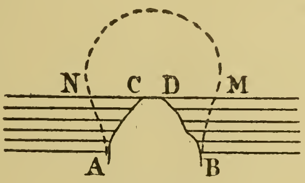


Fig. 25.

Fig. 25 shows how a bell is formed. In this case the bell may be a kind of truncated cone ABCD; but if the ground is comparatively soft or mobile, and the height of the excavation great in comparison to the height of the ground above it, the truncated cone is inverted ANMB.

The following diagram (Fig. 26) shows how the position of the subsidence varies according to the depth of the excavations below the surface—and explains how observations which seem to be diverse from each other and often contradictory, are not really so.

AB is an excavation : ABCD the zone of subsidence.

When S represents the level of the surface there is no appearance of subsidence.

At the level S_1 there is a small subsidence limited on the right-hand side by the normal BC, drawn from the highest point of the excavation.

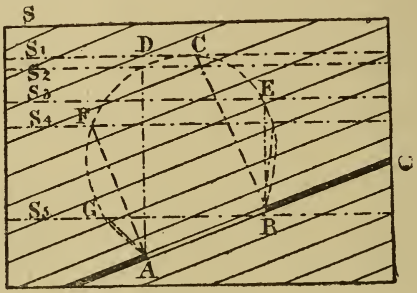


Fig. 26.

At the level S_2 the limit of the subsidence on the left-hand side corresponds to the vertical AD drawn from the lowest point of the excavation.

The limits of the subsidence coincide on the right with the vertical BE at the level S_3 ; on the left with the normal AF at the level S_4 ; and on the level S_5 with a line inclined at 49 degrees drawn from the lowest point of the excavation.

THE COST OF SECONDARY HORSE HAULAGE.

By Mr. W. J. Heppell.

Considerable attention having recently been given to the cost of secondary haulage and the question of the substitution of mechanical haulage for horses, possibly a short Paper on the cost of horse haulage in a South Wales colliery may not be without interest to the Members of the Institute.

For this purpose the writer has taken out particulars at Cwmaman Colliery for the fortnight ending 20th February, 1897. The distance from the inbye end of the engine plane to each collier's stall was measured, and the quantity produced from each stall taken. A record was also kept of the quantity of rubbish, and the distance it was conveyed. Practically, the whole of the rubbish is stowed underground, a large quantity being sent from one district to another, and very little brought to the surface.

The quantity of coal brought out during the fortnight from the districts in question was 12,615 tons. Wages, subject to the sliding scale, were taken at standard rates. The total cost of the horses for the year 1896 was as follows:—

	£
Horse-feed and bedding	1,625
Replacement of horses*	500
Saddlery	307
Veterinary, farrier, and medicine	135
Shoeing iron, tools, &c.	34
Shoeing smiths	131
Smiths, on shafts, &c.	40
Ostlers	437
Making and maintaining stables	100
	£3,309

---

* This is much in excess of the usual amount. In 1895 it was £310, in 1894 £250; but against this the cost of horse-feed was low in 1896.

which was equal to £35. 19*s*. 4*d*. per horse for ninety-two horses (including farm and coal-hauling horses and horses opening out new seams), and for 294 working days was equal to 2*s*. 5·3*d*. per horse per day. In the following calculations 2*s*. 6*d*. per horse per day has been taken as the cost, and 3*s*. 6*d*. per day for haulier's wages.

The bulk of the trams weighed when empty 11 cwt., and carried on an average 28 cwt. of coal; but about one-fifth were of an older pattern, weighing when empty 10 cwt., and carrying 24 cwt.

Cwmaman Colliery is an old colliery, and the shafts are sunk at the extreme east of the property, the districts extending:

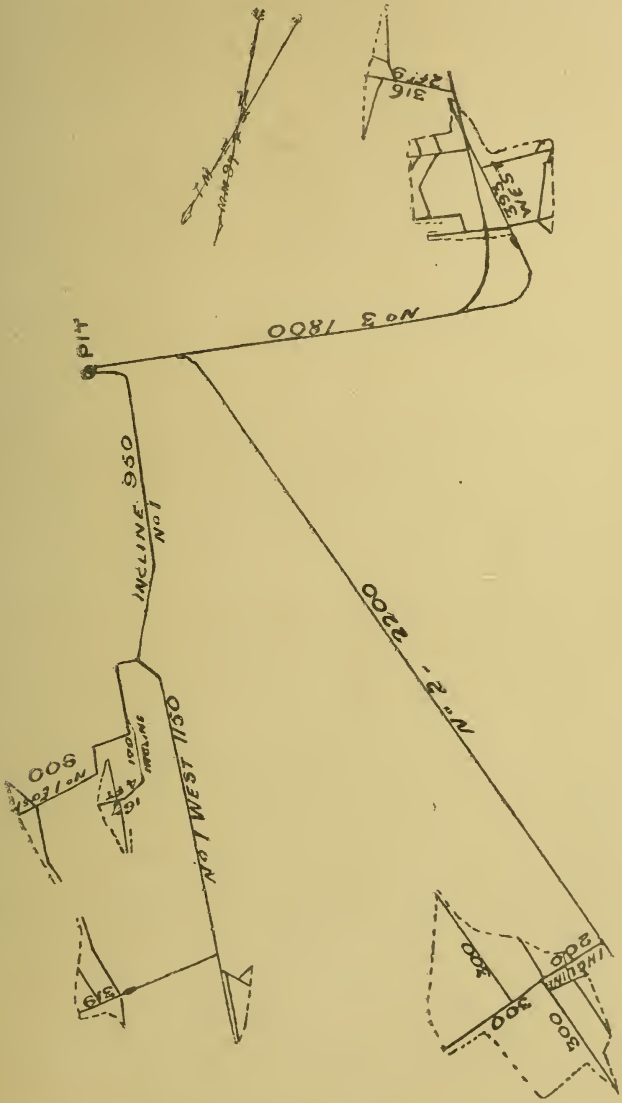
No. 1. . .	$1\frac{1}{2}$ mile to the north-west.
No. 2. . .	$1\frac{3}{4}$ mile to the west.
No. 3. . .	$1\frac{1}{4}$ mile to the south.

And as the workings in some cases extend to a considerable distance, one of the engine planes being $1\frac{1}{4}$ mile in length, it would be costly to adopt any mechanical means for inbye haulage.

No. 1 *district.*—The coal is brought to the pit by means of a self-acting incline 950 yards in length, with an average gradient of 3 inches per yard, worked by means of a 9-feet drum, with 1-inch steel wire-ropes. The coal to the east side of this incline is brought all the way by horses, the average distance from the face in the 6-feet seam being 900 yards. At 290 yards from the top of the main incline another self-acting incline is driven to the 4-feet seam 170 yards in length, with a gradient of 5 inches per yard. The average distance from the top of this incline to the face of the coal is 169 yards. This coal is brought to the inclines by means of horses.

The coal to the west side of the main self-acting incline is brought to the top of the incline by a hauling engine working main and tail, the engine plane being 1,150 yards in length.

The average distance from the face of the coal to the inbye end of this engine plane is 319 yards, the coal being brought this distance by horses.



No. 2 *district.*—The coal is brought from the district by means of a hauling engine working main and tail, the length of the engine plane being 2,200 yards. From this point an incline to the 4-feet seam is driven, 200 yards in length, and working self-acting. From the top of this incline to the face the average distance is 300 yards, worked by horses.

No. 3 *district.*—The coal is brought to the pit by means of a hauling engine working main and tail, the engine plane extending 1,800 yards; the average distance from the inbye end of the engine plane to the face is 316 yards in one district, and is 393 yards in the other, worked by horses.

The particulars of the costs of the various districts are given in the table on page 347.

It will be seen from the table that the distance the coal had to be brought by horses varied from 169 to 900 yards, and that the cost per mile ton on the coal and rubbish, by day, varied from 7·7*d.* to 1*s.* 7*d.*

There is very little difference in the absolute cost per ton in each district except in the 2 feet 9 inch district, where the coal carried is 4 to 5 cwt. per tram less than in the other districts, owing to the coal not being so hard and strong.

No. 1 district (4 feet) is a new district, and the work was rather too much for two horses, but not enough for three horses, and, as the output has increased, this cost has been reduced.

In No. 2 district the heavy cost is due to the amount of rubbish that is necessary to take in from other districts, very little being made in this seam itself.

CWMAMAN COLLIERY. FEBRUARY 1897.

District	Tonnage	Mile Tons of Gross Coal	Average Distance—Yards	Rubbish				Day Work			Night Work			Cost per Mile Ton on Coal only on Day Horses and Hauliers	Cost per Mile Ton on Coal and Day Rubbish on Day Horses and Hauliers	Cost per Mile Ton on Total Coal and Rubbish on all Horses and Hauliers	Absolute Cost per Ton on Coal only charged on all Horses and Hauliers	Remarks
				Mile Tons—Day	Average Distance—Yards	Mile Tons—Night	Average Distance—Yards	Number of Horses	Days worked by Horses	Days worked by Hauliers	Number of Horses	Days worked by Horses	Days worked by Hauliers					
														s. d.	s. d.	s. d.	d.	
No. 1. East Side .	1,437	738	900	21	247	19	280	9	108	111	2	24	24	0 8·2	0 7·7	0 9·2	4·9	Gradient against the horses, 250 yards 2 inches per yard, then level.
,, ,, .	*1,356	224	290	34	290	10	290											
,, ,, 4 ft.	1,356	128	169	20	131	6	197	3	36	37½	1	12	12	1 8·8	1 5·9	1 10·8		Practically level.
West Side .	2,879	523	319	36	98	36	419	12	144	150	4	48	48	1 8·3	1 7	1 11·7	4·9	Heavy gradient against the horses, about 2 inches per yard.
No. 2 . . .	3,384	578	300	89	196	119	497	14	168	179	6	72	84	1 9·7	1 6·8	1 11·2	5·4	In one-half of this district ¾ inch per yard against the horses, the other half in favour.
No. 3. West Side .	1,915	344	316	49	286	60	241	7	84	87½	3	36	36	1 6	1 3·8	1 7·4	4·6	Gradient generally in favour of the horses.
2 ft. 9 in. District	1,644	366	393	20	334	79	177	8	96	101½	4	48	48	1 7·6	1 6·6	1 11·0	6·4	Half the district is ½ inch per yard against the horses, the other half in favour.
Total . .	12,615	2901	—	269	—	329	—	53	636	666½	20	240	272	1 4·2	1 2·8	1 6·8	—	—

* This is the 4-ft. coal from the bottom of the 4-ft. Incline to the Main Incline.

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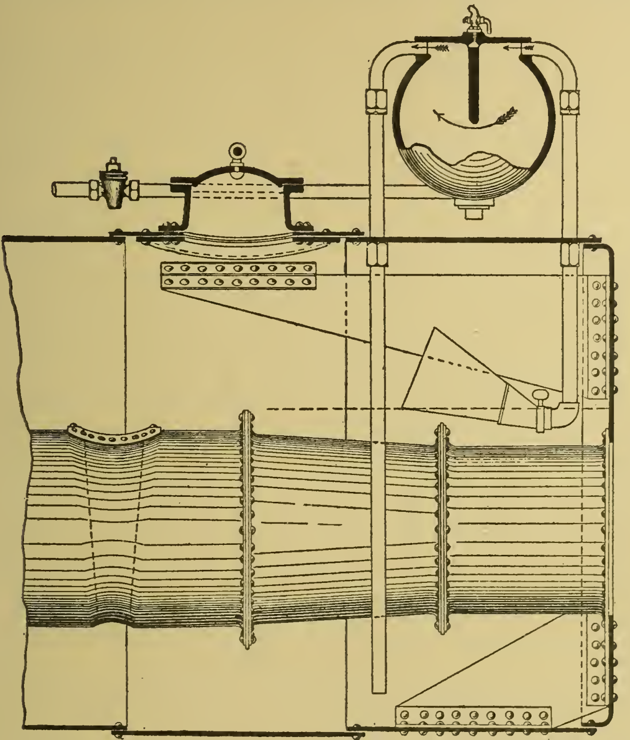

Diagram of "A" Pattern Cleaner, fixed on a Lancashire Boiler.

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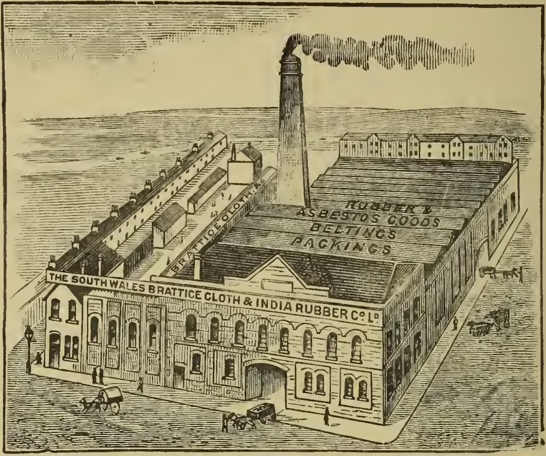

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1897.

(*Ex-officio* Members of the Council.)

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Brown, Thos. Forster, M.Inst.C.E., Cardiff	1873–74, 74-75. 1891–92, 92–93.
Laybourne, Richard, M.Inst.C.E., Newport, Mon.	1877-78, 78–79.
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Stevens, Arthur J., Newport, Mon.	1893–94, 94–95.

Deceased Past Presidents.

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Rogers, Ebenezer	1858–59.
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Brough, Lionel	1860–61.
Adams, William, Assoc.M.Inst.C.E.	1861–62.
Evans, Thomas	1862-63.
Bassett, Alexander, M.Inst.C.E.	1863-64.
Martin, George	1865–66, 66–67.
Williams, Edward, M.Inst.C.E.	1881-82, 82–83.
Colquhoun, James	1883-84, 84-85.

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ISSUED DECEMBER 4TH, 1897.

VOL. XX.] [NO. 6.

PROCEEDINGS

OF

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[EMBRACING THE COAL-FIELDS OF SOUTH WALES
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4th October, 1897.

EDITED BY THE SECRETARY.

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NOTICES.

The EDITOR of these Proceedings is directed to make it known that the Authors alone are responsible for the facts and opinions contained in their respective Papers, and the individual Speakers for their Statements made in Discussion.

All communications to be addressed to the Secretary, Mr. HORT. HUXHAM, Swansea; from whom back Numbers of Proceedings may be had, and also printed Forms of Application for Admission of Candidates as Members.

CHANGE OF RESIDENCE.

The SECRETARY would be obliged by Members notifying to him any alteration in their addresses at the earliest date.

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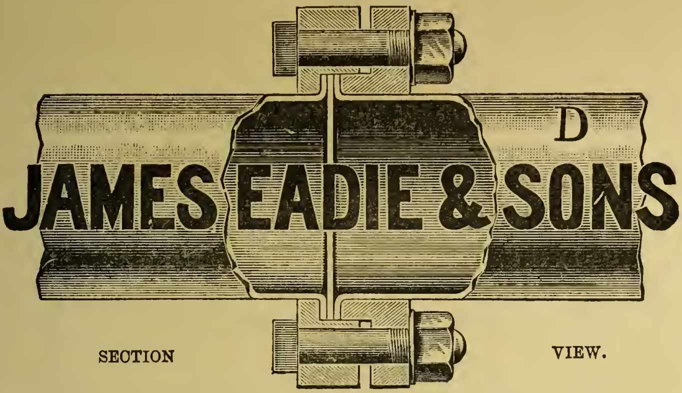

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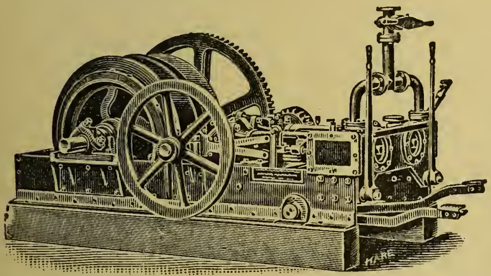

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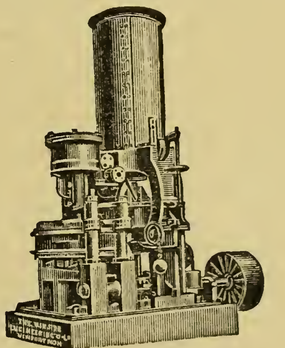

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PROCEEDINGS.

4th October, 1897.

The General Meeting of the Institute was held at the Lecture Theatre of the Institute, Park Place, Cardiff, on Monday, the 4th October, 1897.

Mr. HENRY W. MARTIN, M.Inst. C.E., President, in the chair.

The Minutes of the last General Meeting were read and confirmed.

ELECTION OF NEW MEMBERS.

The President announced that the Ballot Lists had been opened by the Scrutineers, and declared the following gentlemen duly elected to the Institute:—

As Members.

Allen, James	Cardiff.
Geen, George	Newport.
Jenkins, Sir John J., M.P.	Swansea.
Jones, John J.	Johannesburg.
Phillips, Nehemiah	New Tredegar.
Thomas, R. Beaumont	Chepstow.
Treharne, J. Ellis	Blackwood, Mon.
Wright, J. Roper	Gowerton.

As Associate.

Hooper, Robert	Cardiff.

ADMISSION OF NEW MEMBERS.

The following gentlemen were admitted to the Institute, and signed the Roll Book, viz.:—

PHILLIPS, NEHEMIAH	New Tredegar.
THOMAS, ILTID EDWARD	Swansea.
TREHARNE, J. ELLIS	Blackwood.

DISCUSSION ON "SUBSIDENCE CAUSED BY THE WORKINGS IN MINES."

The President. The PRESIDENT said that the first matter on the agenda was to discuss the Paper of Professor W. Galloway on "Subsidence caused by the Workings in Mines." Perhaps Professor Galloway would open the discussion.

Professor W. Galloway. Professor W. GALLOWAY said, as the Paper was mostly a *résumé* of the opinions and experiments of Continental engineers, and was not an original contribution on the subject, he did not feel that responsibility which he would otherwise have done. In discussing the Paper, therefore, members would be kind enough to remember that they were discussing the opinions of eminent Continental engineers and not his; but if he could assist in throwing any further light on the subject, he should be very glad to do so. The subject was involved in a great amount of obscurity on account of the difficulty of making correct and exact examinations of what actually took place in the interior of the earth when the break occurred. As those who had read the Paper would have noticed, the first very important question which arose in connection with subsidence was that which involved the safety of part of the town of Liege, in Belgium. The opinion of the gentlemen who were

Professor W. Galloway.

consulted by the Town Council of Liege seemed to be that if a solid crust of ground, of some 100 metres in thickness, were left above the workings, that was to say, a crust in which the seams of coal were not to be worked, the buildings on the surface would be safe. As would be gathered from the Paper, the workings were carried on for a certain number of years, and it was found that a crust of 150 or 200 metres in thickness, as the case might be, was not sufficient to prevent the surface from being broken up, water-pipes displaced, and houses cracked to a large extent.

Then came on the Commission which examined the subject, and appointed M. Dumont, the first engineer whose opinions were given in the Paper.

M. Dumont investigated the subject closely. He had a large number of levels taken all over the town of Liege, which was the only proper way of ascertaining whether subsidence had happened or not. He examined the plans of the workings, and he thought he discovered that the break of the strata always took place at right angles to the dip of the seam, and this was known as the Normal Theory. Now, as he had mentioned in the Paper, the plans which M. Dumont reproduced, and the nature of the strata, and the varying dip of the seams, and so on, introduced so much complication into the subject that it was impossible to draw any perfectly convincing conclusions from anything he had observed, and therefore he passed over M. Dumont's observations by simply recording them as he had done in the Paper.

On the other hand, M. Fayol, who was a well-known scientific mining engineer in France, investigated the subject carefully. He followed the only way of scientifically investigating the matter. He had chosen certain mines where there were no complications due to faults, or to the seams being contorted as they were under Liege, and he then

Professor W. Galloway. took levels across the ground before the workings were commenced at all. Having taken a series of levels across the ground, he observed the action of the workings for a series of years, taking levels at regular intervals to ascertain in what way the ground was sinking. Having in that way found out what actually took place, where the area of subsidence occurred in reference to the working of the seams, he then formulated a theory which he expressed in the words quoted in the Paper, viz.: "The movements of the ground are limited by a kind of dome which has for its base the area of the excavation; their amplitude diminishes by degrees as they extend further away from the centre of that area." The best illustration of that theory was found at the very end of the Paper, in figure 26, in which case the seams are shown to dip at a slight angle.

M. Fayol said, that if the depth of the working below the surface bore a certain proportion to the area worked, then the subsidence would reach the surface, or not, according to the actual depth of the workings below the surface. For instance, as shown in figure 26, there was a certain height at which the subsidence would not reach the surface at all. M. Fayol said that at a depth of 800 yards the subsidence would not reach the surface. Therefore, one man making this observation from his own experience, and finding no subsidence at the surface, was apt to conclude that no subsidence takes place. Another, who had the same experience, but with a less depth, found a subsidence taking place between the points D and C, and he immediately jumped to a different conclusion. He also found that the line drawn from D to the edge of the excavation at A was vertical, and he concluded that the subsidence took place vertically above the area worked out. Another, who worked with a still smaller depth, found that a line drawn from the edge of the subsidence at F to the edge

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of the excavation at A was at right angles to the dip of the seam. He therefore concluded that the subsidence took place normally, or at right angles to the seam.

Thus each observer according to his own experience formed a different opinion as to the line of the break of the strata; and it was in order to see whether his own conclusions were confirmed by experiment, or not, that M. Fayol made the experiments which were described in the Paper. Those experiments appeared to confirm his conclusions exactly; but they were made upon a small scale, and they must only be taken for what they were worth. M. Fayol was not so positive or dogmatic in his conclusions as to exclude the possibility of some modification of his theory being introduced, and he concluded his opinions by expressing the hope that other engineers would give their attention to the subject, and record their experience.

Now, he (Professor Galloway) thought he had given a fair idea of the conclusions arrived at by the two authors whom he had quoted. His object in bringing this Paper before the Institute was to try to induce members who had the opportunity to go and do likewise—that was to say, make careful and close observation of the manner in which the ground broke above the workings of the mine with which they were connected. If members would take the trouble to level the ground at regular intervals across the ground where the subsidence was taking place, and bring the records before the Institute, they would then have a chance of corroborating, or otherwise, the conclusions come to by M. Fayol. The subject was one of great interest and importance.

He might state that his own opinions were open to conviction on the subject. On one occasion he was asked to give evidence before a court in Scotland as to whether a house had been damaged by subsidence. In that case the seam of

Professor W. Galloway. coal, six or eight feet thick, was nearly vertical, and the workings had been carried to a considerable depth. The surface of the ground rose slightly for some distance from where the coal was worked towards a house which had been built some 500 yards away, at a cost of between £3,000 and £4,000. After the workings collapsed, the ground in the vicinity of the house began to crack and slip. It consisted of running sand, and he concluded at that time that the vibrations due to the breaking of the ground had been transmitted through the rocks, and had set the running sand in motion.

He had seen one great break on the side of Aberdare mountain, and another near Margam, in the South Wales coalfield, but having no plan of the workings before him, or any levels to show how the breaks were related to the workings, it was impossible for him to form any opinion as to whether those cases upheld M. Fayol's theory or not.

Mr. H. K. Jordan. Mr. H. K. JORDAN said in his early youth, in the year 1857, when he had charge of a small colliery in the Forest of Dean, he had experience of a case of subsidence. The coal was dipping about 18 inches in a yard, was about 8 or 10 feet thick, and the shaft was about 30 yards deep. A house stood on the dip side of the level heading. Those connected with the colliery were of opinion that, because the heading was on the rise side of the house, the house would not be affected. The coal was worked in the neighbourhood of the house, and he was sorry to say the house went to pieces. That gave rise to a lawsuit which is quoted in legal text-books as "Henry Crawshay *versus* Wagstaffe." The destruction which overtook that house confirmed, he thought, the Normal Theory entirely. Circumstances had prevented his reading the Paper throughout, and he had asked the writer, before entering the room, whether the increase of volume resulting from the abstraction of material from the coal-mine was solely due to air space between the particles, or whether any experiments had been made to determine whether any increased volume occurred simply from relief of pressure. He was not aware whether the Paper referred to that point; but he took it that the great increase of volume mentioned in the tables was due to the air spaces between the particles. **Mr. H. K. Jordan.**

Mr. E. M. Hann. Mr. E. M. Hann said he believed that in Lancashire it had been found that working seams of less thickness than was stated in the Paper had affected the surface at a depth of 800 yards. His recollection of the matter led him to believe that the seam was not more than three feet thick. He was inclined to think that if they worked a sufficiently large area, the break would come to the surface if the working was 2,000 yards deep. With reference to the highly inclined seams, this was a very interesting portion of the Paper. It must naturally follow, he thought, that the line of break would be affected by the character of the rocks themselves. If there were thick beds of sandstone, it would be quite possible, he imagined, for the break, instead of taking place at the normal, to actually overhang the vertical line; but with such strata as were usually met with in the lower coal measures of South Wales, where fireclays and soft black shales formed a large percentage, he could quite understand they were not sufficiently strong to do that, and that the line of break approached very nearly to a line perpendicular to the dip and rise. It must, to a great extent, be a matter of strength of strata. Those who had to do with mines of high inclination should be in a position to prove whether this was so or not. There were mines in the south and west of the South Wales coalfield of high inclination, and were nearer to the Pennant rocks, whereas the steam-coal seams were in the lower strata, with only shales to cover them.

The President.

The PRESIDENT believed that Mr. Hann had had experience of subsidence having occurred where the water had been taken out of flooded mines, without more coal having been abstracted.

Mr. E. M. Hann.

Mr. E. M. HANN said he had had no experience of that kind, but in the county of Durham it was notorious that where pillar and stall was worked, if water was taken out of coal workings left with the pillars in, there were often serious subsidences. But as far as he had been able to ascertain, taking water out of seams worked on the long-wall system had not produced any movement on the surface.

Mr. James Barrow.

Mr. JAMES BARROW said the subject was of extreme importance. It happened to be one to which he had devoted a great deal of attention. He could confirm the theory put forward by the engineer referred to in Prof. Galloway's Paper, that the break invariably occurred as near as possible at right angles to the dip of the seam. Of course, it varied according to whether they were in the upper sandstone measures or in the lower and softer strata of the coalfield. As to the thickness of the seam which might affect the surface, he agreed with Mr. Hann. His experience showed him that it was only a question of area of extraction. He had a case in mind where the vertical depth was 2,400 feet, and where subsidence caused buildings on the surface to crack, water and gas mains to be broken, bridges to be squeezed and distorted. The workings in that case were not more than 5 ft. 6 in. to 6 ft. 6 in. in a clean seam of coal. There was a certain quantity of stowing put in arising from the débris in the working of the seam, including the ripping of the roof. It was worked entirely on the long-wall system. That was the deepest section that had come under his notice. As to the leaving of pillars, if they were left of sufficient size, having regard to the position of the workings, there was no doubt it was practicable to leave enough to protect buildings

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on the surface. In nine cases out of ten, however, where he had been called in, the manager had left too small a pillar. By not leaving sufficient pillars to protect the area covered by a break at right angles to the dip of the measures, the break had come right through the middle of the premises, which it had been the object to protect. As to the depth at which mischief might arise, much depended upon the thickness of the seam and the character of the strata which they were working under, and also the character of the gobbing. He recalled a case of workings going on under a church which had a very fine steeple, about 100 feet high, and which when he was called in was something like two feet out of plumb. Upon his advice, the ordinary Welsh long-work was replaced with the Barry system, no pillar was left at all, and as fast as the coal was taken out stowing was put in. The result was that in the course of nine or twelve months the steeple of the church had actually reverted to its original position, and was as perpendicular when they finished working as it was when built. Within the present year a similar case had come under his notice. The workings were at a depth of about 220 yards, and were worked by the Barry system, and every night the stowing—such as it was—was put in so as not to leave any waste in the gob, but done systematically throughout, props and timber being taken out. The result was that up to that moment no effect had shown on the surface. There were large windows in the building on the surface, and not one of them was cracked, and there were no cracks or displacement of the stonework, yet the working face had gone 150 yards beyond the buildings. Of course they could not always adopt the Barry system, the roof and the width of the stalls might not admit of it, nor the inclination of the seam. Each case had its own special set of circumstances, which required careful consideration. In one case he was very dubious.

Mr. James Barrow.

Above the seam of coal, six feet thick, there was only about six to eight feet of a crust of shale, and from there to the surface were alluvial sand and boulders. Nothing remained to be done except paying for the coal, and this was done. One night after the parties had settled, instead of the places being stowed up, as had been agreed upon, some of the timber had been surreptitiously removed, and the result was a fall the next morning. There was a crowning in that had gone right up to the surface, letting in daylight. He did not know whether Professor Galloway only meant to include seams of coal or also hematite workings. He had knowledge of a case of such workings taking place under a shunting station. One morning when the driver of an engine was having his breakfast in an adjoining cabin, his locomotive and tender suddenly disappeared down a hole, caused by a fall in the workings beneath. As to the general conclusions of the Paper, there was no question that the break of the strata took place nearly at right angles to the dip of the seam, much, of course, depending upon the nature of the strata overlying the seam, and also overlying the next strongest rocks or stones or strata that might be intervening between there and the surface. As to the steep measures, he had worked a good deal as nearly as possible vertical down to the horizontal. He remembered a case where, working a vertical seam, a spring of water was affected more than half a mile away. As soon as the working was stopped, and pumping ceased, the spring recovered itself, and it had been running from that day to this. There was a valley between the site of this pit and the spring, and a considerable amount of alluvial deposit. It had been a great gorge at one time and had gradually filled up. It was well known that the workings did cause a subsidence some distance from the pit itself, and that the effect was to bring the spring down to the workings.

Mr. I. Treharne Rees.

Mr. I. Treharne Rees said this subject was perhaps not so

Mr. I. Treharne Rees.

important in South Wales as it was in the Midlands, where subsidences often were matters of dispute and litigation. He observed that not one of those who had spoken had expressed a single opinion as to the theory he had himself formed, but had been content to simply refer to the theories of Continental engineers. To his mind the theory of M. Fayol was approaching correctness, for when they came to think of the matter, if there was a building to be supported on the surface, and the coal was being worked at no great depth, they left the pillar very nearly vertical under it. But if there were heavy buildings to support, and the coal was being worked at greater depths, the angle of draw became greater, and a larger pillar would be necessary to provide a sufficient support; but it stood to reason that when they got to a certain depth, whether it was 800 yards or more, they need leave no pillar at all. Thus the angle which they had to take for the support of any surface structure could not be a constant one. He noticed among the examples given from the Commentry mines, that in a seam 3·28 feet thick, if no stowing was used, there was no appreciable subsidence at a depth of 200 metres, or, roughly speaking, 220 yards, and that if stowing were used there was no subsidence at a depth of 80 metres, or 90 yards. Now he thought a great deal depended upon the strata which lay above the seam and between that and the surface, or between that and the object which it was necessary to support. In the lower steam-coal measures of South Wales he knew of a seam, practically flat, between three and four feet thick, worked on the long-wall system and well stowed. One hundred and twenty yards above this seam, workings had been prosecuted in another seam in advance of the seam below; and although there were 120 yards of intervening strata, and the openings caused by working the seams were well stowed, yet the workings of the seam above were

Mr. I. Treharne Rees. affected a distance of 50 yards in advance of the workings of the seam below. This was in the ordinary steam-coal lower measures of South Wales, not in the sandstone rocks. He could easily understand a vertical break in the sandstone rock, and also not so vertical a break in softer strata. In driving a railway cutting through rock the slopes were made ½ to 1, and it stood; but if in soil it would be necessary for the slopes to be 1½ to 1, and this difference in the hardness and the density of the substances was the same with regard to strata, and had to be taken into account.

Mr. Thomas Evens. Mr. THOMAS EVENS said he did not believe they could have a theory which would be applicable to all cases of subsidence. Faults interfered to a very considerable extent with the action of the strata breaking. He had a case in his mind. About 30 feet of coal had been taken out on one side of a fault, having a downthrow east of about 60 yards. On the west side of the fault there was a crack, into which a railway train could be put, and the surface generally had sunk about 25 feet. On the eastern side of the fault, however, where the same quantity of coal had been taken out, there was apparently no subsidence at all. He could not account for it, except that the ground on the western side had slipped down into the valley—it was on the side of a mountain—and the pits being very much crushed, especially in the middle, seemed to confirm this idea, although fair pillars were left for their protection. Speaking generally, he objected to pillars, and, where there was plenty of cover, would work all the coal out, and if there were any buildings about he would thoroughly stow the openings as quickly as possible after taking the coal away. Buildings were saved better that way than by leaving pillars. A pillar to protect buildings on the surface required to be so enormous that, in most instances, it would pay to remove the buildings to another spot.

Mr. Theodore Vachell.

Mr. Theodore Vachell said he thought it entirely depended upon circumstances as to the amount of pillar to be left. In Monmouthshire, for instance, working one seam over another, if there were strong ground between two seams, 50 yards between each other, he invariably found the break was behind the face of the coal; if the ground was weak it broke forward, and in a great many cases the break was almost vertical with the seam. With regard to the size of pillar to be left, it entirely depended upon the strata overlying the seam and upon the nature of the surface, whether hilly or flat, and the thickness of coal to be taken out. His experience showed him that at a depth of from 200 to 300 yards, if a substantial pillar could not be left, it was a great deal better to take out the coal altogether. It was impossible to fix any regular rule as to the area of pillar to be left to support the surface.

Mr. E. M. Heppell.

Mr. E. M. Heppell (Radstock) recalled a case of six or seven years ago at Oldham. They were working a seam only two feet thick under a densely-populated district and on the long-wall system. No appreciable damage occurred, but just as the pit was finishing and they had worked up against the boundary, which was to the rise, the strata rising about five inches to the yard, claims were made upon the owners by people whose property was over the boundary. After he had left he believed compensation was paid. The depth was about 125 yards, the seam, as he had said, about two feet thick, with a very good top, and the break extended not only over the line of right angles to the seam, but forward into the neighbouring property, doing considerable damage to buildings standing on the roadside. The actual boundary was a street, and he saw a church and a manufactory on the other side of the street very badly damaged, undoubtedly by the workings 120 yards deep.

note

Mr. G. E. J. McMurtrie.

Mr. G. E. J. McMurtrie wrote that he had read with

Mr. G. E. J. McMurtrie. great interest Professor Galloway's valuable Paper on "Subsidence caused by the Workings in Mines," and which embraced the principal results of M. Fayol's experiments and investigations on the subject.

This subject and report were some years ago considered by the British Society of Mining Students, and a number of examples of the results of subsidences were described, which he thought were of sufficient interest to bear quotation.

It was stated by Mr. Robert Dron, of Earnoch Colliery, that the principal movement took place in the first twelve months, and that it was two years before it ceased.

If the system of working was long-wall, and the face of the workings was parallel to the long face of the building, it would probably not be affected. When, however, the long-wall face was worked in steps and the narrow way of the house, the back of the house was generally broken. Thus the Torbane Hill mineral, 2 ft. 6 in. thick, was worked at Bathgate under several shops with large plate-glass windows, and no injury was done.

With pillar working the settlement was more irregular, unless the face was worked in a long range, and then the subsidence was 60 to 70 per cent. of the thickness of the seam.

It was stated that the engineer of the Caledonian Railway Company allowed under their bridges 4½ ft. perpendicular to 1 ft. horizontal for the "draw," while some allowed 3 ft., and some even 2 ft. to 1 ft. horizontal. ft.

note

At the Bent Colliery the ell coal, with a 5 ft. 6 in. section, was worked at a depth of 670 yds. The inclination was 1 in 20, and the system of working board and pillar. Mr. J. S. Dixon levelled a line and fixed pegs every 50 ft. for a distance of 1,230 ft. and parallel to the level course of the seam and at right angles to the coal face. Goafing was begun at the end of 1881, and completed in the middle of 1884. The first

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subsidence took place May 27, 1882, when the face was 400 ft. from the solid coal, and Mr. Dixon continued to take levels to the end of 1885.

The maximum subsidence was in the centre, and amounted to 4 ft., or 73 per cent. of the section of the coal, and tailed off to either end. It was stated that the wave of maximum subsidence followed 186 ft. behind the working face, or 1 ft. horizontal to 3½ ft. vertical, while at the two ends of the line the permanent draw was 100 ft. and 83 ft. respectively, or 1 in 6·5 and 1 in 8·18. The time of settlement was 18 months after goafing. It was found that the draw in the direction of the rise and dip was much the same.

A colliery in Derbyshire was instanced by Mr. J. W. Longden, where the seam was 520 yds. deep, with a shaft pillar 260 yds. × 800 yds., with a flat inclination; yet creep came on, and it was feared that the shaft would be lost, the pit bottom arching having to be put in three times—and finally with alternate layers of oak and brickwork—owing to bad packing of the goaves. It was considered that the shaft pillar should have had a radius of half the depth if the seams were flat, and if the measures were inclined, that an additional area should be allowed on high side of shaft.

It was stated that two seams of coal, each 4 ft. thick, had been worked at depths of 200 and 260 yds. on the longwall system under two rows of 120 cottages, with but little damage being done owing to the line of the coal face being kept at right angles to the line of the cottages. The effect of working under a long stone wall was also described, the line of the coal face being at right angles to the direction of the wall. The effect was to cause the wall to slope away from the goaf and to lean over the solid coal, so that it had to be buttressed. In both of the last cases he (Mr. McMurtrie) considered that the direction of the coal face should have

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been parallel to the long side of the cottages and to the wall.

A house above the same seams, when the workings were 50 yds. off, opened at the top where wings had been added; as the coal was worked from under it and beyond, the cracks came together again and the house settled down without any real damage.

It was stated by Mr. H. F. Bulman that at Byer Moor Colliery, pillars 50 yds. × 33 yds. were worked off by 8-yd. bordway's lifts; section of coal 5 ft., depth from surface 70 fathoms, roof solid sandstone for at least 4 fathoms above seam. An area of 2,500 sq. yds. of goaf had been made in three months without a fall. Then, after half an hour's warning, the whole area came in with a sound and action like an explosion. The plane of fracture of the beds was not vertical, but highly inclined over the excavation.

Instances were given by Mr. W. S. Gresley in working a 12-ft. seam of coal, of which 7 ft. was worked with a waste of 33 per cent., leaving 4 ft. 8 in. sent out of stall. System of working, long-wall to the rise. Owing to the draw, the manager's house was cracked and began to sink 50 ft. in advance of the working face 390 ft. beneath it. The total subsidence, as measured on the canal, was 2 ft. 6 in., and the strata consisted of 20 yds. of sandstone, with binds and coal seams.

In another instance the coal on the east side of a fault was first worked out, and no effect was noticed on the surface. The coal was next worked on the west side of the fault, and a conspicuous break or bend soon showed itself for hundreds of yards on the surface in the line of the fault, with a difference of level of 3 ft.; the system of working was the same on either side of the fault, and only 1 ft. more coal was got on the west side of the fault. The hade of the fault was 72 degrees.

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A 6-ft. seam of fireclay was also worked at a depth of 180 ft., with the measures solid to the surface, and no waste of clay and no gobbing. A brick and cast-iron girder railway bridge, vertically over where the face or edge of the workings stopped for some time, was ruined.

Some 10 ft. of a 14 ft. seam of coal was got at a depth of 229 yards. Eight years later a rock heading was driven 20 yards over the top of this thick coal-gob to cut some coal beyond a fault, and for some distance a horizontal open cavity or space was encountered 18 to 36 inches high, where the strata had clearly been once in contact, and that was an instance of the inability of the coal measure strata to subside regularly and fill up the settlements.

In Iowa, with pillar and rib working, the pillars and ribs being 7 ft. thick at a depth of 70 ft., of which 60 ft. was alluvium, Mr. Gresley observed open cracks formed on the surface about a yard apart and roughly parallel, just where the subsidence reached the surface and vertically over the robbing of the pillars.

In Pennsylvania, when working the Mammoth Seam (40 ft. thick) lying at a dip of 70° to 80° in chambers, or narrow stalls, the whole seam and surface over it to the outcrop frequently ran in and formed caves or cropfalls all along the hillside.

The removal of 50 ft. of the Mammoth Seam at a dip of 25° was said to cause a subsidence of 8 ft. only, the strata being binds, fireclay, sandstones, and thick beds of quartz conglomerate, which were intensely strong, and might possibly account for such a small subsidence.

The following table, prepared by Monsieur Crespin, the engineer of the Bully Grenay Company, shows the average compression produced by the settlement of the roof in different seams:—

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Names of seams	Kind of roof and floor	Inclination of strata	Thickness of seams	Thickness of stowing after settlement	Reduction from original thickness (percentage)	Remainder after complete settlement (percentage)
			metres	metres	per cent.	per cent.
St. Jean . .	—	25°	1·40	·76	46	54
St. André . .	—	25°	1·30	·73	46	54
St. Barbe . .	Good roof and thill	15°	3·00	1·57	48	52
St. Alexis . .	Soft roof Spongy thill	5°	1·30	·64	51	49
Charlotte . .	Roof fairly good Good thill	5°	1·20	·70	42	58
Simphorien .	Soft roof Good thill	5°	·75	·40	46	54
	Total		8·95	4·80	46	54

An instance was quoted by Mr. A. W. Grazebrook of working the Staffordshire 10-yd. coal at Conygre Colliery, at a depth of 325 ft. below the surface. A square of work was cleared of all its pillars save two small ones, leaving a space of 40 yds. square and 33 ft. high with nothing but these two small supports. The inclination was 1 in 15. The position of the crownings in on the surface, *i.e.*, a pit formed by the subsidence of the ground of a somewhat similar shape to the swallow holes of the limestone districts, was at right angles to the inclination. The overlying strata consisted of soft argillaceous shales and clays, with harder beds of sandstone and one seam of workable coal. The working of this block of coal lasted from September 1889 to March 1890, and the crownings in took place on October 5, 1891—18 months after. The subsidence was oblong in shape, measured 28 by 18 ft., and the strata went down 26 ft. Three of the sides went sheer down, and the fourth hung over slightly at the top. No faults,

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slips, or faces were met with in the coal, and the ground round the hole did not settle or give way, and there were no breaks or cracks visible.

The writer could give one or two instances from his own experience. A surface incline used for lowering coal trucks sank considerably where a total thickness of coal of some 8 ft. had been worked. The depth of the pit to the lowest seam worked was 278 yards, and the strata rose 2 in. to the yard.

The incline lay to the rise of the pits, and some 240 yards of the incline subsided for a depth of 2½ feet for the greater part of that distance, tailing out to the original level at each end. The coal had been worked 400 yds. to the rise, whereas the subsidence of the surface appeared to have continued a further distance of 13 yards. It was interesting as showing that even in a thin seam district the surface was slightly affected by coal working.

At the same colliery the offices had been slightly disturbed. The offices were situated on the edge of the shaft pillar, and adjoined the stores, carpenter's and smith's shops. The office itself had been drawn very slightly towards the gob, but showed no cracks, although the doors were affected. Cracks, however, appeared on both sides of the stores. The probability was that the movement marked the draw over the edge of the pillar. It was to be noted that the settling still continued, although the movement was very slight, and although it was now fifteen years since coal of any thickness had been worked, and six years since a thin seam of coal was worked.

The strata was of the usual coal-measure type, chiefly binds, blue metal, and clod, with a small thickness of strong sandstone.

In working both the Lowrey and 20-inch seams in the Forest of Dean, much trouble was experienced by the occur-

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rence of what were locally termed "grinds." These were especially common in the 20-inch, and in that case sometimes penetrated the roof, so that the collier occasionally passed from one piece of coal to another two or three inches higher.

The following was an abridged section of the strata at the pit :—

	ft.	ins.	yards.
Surface to 20-inch			215
Twenty-inch coal	1	8	
Strata, consisting chiefly of clod and soft binds			14
Lowrey seam	2	10	
Strata, consisting chiefly of strong bastard rock and sandstones			28
Rocky coal	1	10	
Strata, consisting of strong blue metal and binds			21
Highdelf coal, 2 ft. 6 in., or, including bottom coal	3	6	

The Highdelf, being the thickest coal, had, as usual, been worked first, and the Rocky was worked next, followed by the Lowrey. It was only during the last ten years that the 20-inch had been generally considered workable. As far as the writer could learn, no such effects were experienced in the Rocky seam, but the working of the Rocky, or of the Rocky and Highdelf, had certainly affected the Lowrey, and probably the working of the latter had produced those grinds in the 20-inch. The grinds in the Lowrey appeared as sooty slips, 3 feet to 4 feet apart, with crushed coal on the one side, but seldom affected the roof, though the slip took all the weight off the coal. In the 20-inch, however, the slips, though of a similar character, were two to three feet apart only, and ran for a greater length along the coal face. The roof, too, was generally affected by them, the soft over-clod being either so greatly crushed that it could not be kept up, or else it was cut off along the line of the slip. In neither seam was the floor

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said to be affected, although the writer believed that this must have been the case, but was not recognised owing to the local system of holing in the under-earth.

The stronger strata up to the Lowrey had clearly protected that seam, and the weaker strata between the Lowrey and 20-inch had caused the 20-inch to experience the full effects of the subsidence caused by the working of the Lowrey coal.

Professor W. Galloway

Professor W. Galloway, in replying on the discussion, said if members would apply their experience to M. Fayol's rule, they would find it was not very far out after all. At any rate, the French engineer put it forward as a tentative theory; and in order that that theory might have fair play it was only right that they should have actual measurements and levellings to go by, and not merely what was seen by the eye. Of course one knew the depth of the seam under the surface, but the actual position of the subsidence, and its amount at various parts, was not to be easily judged by the eye, or so easily as it would be by a series of effectual levellings. Now Mr. Hann had mentioned the case of a canal affected at a depth of 800 yards. When he was in the act of compiling this Paper, he had in his mind the case of canals in this district affected by the working of a seam six feet thick at a depth of between 400 and 500 yards; and this occurred to him to be contrary to M. Fayol's conclusions. Mr. Barrow, on the other hand, cited the case of buildings being affected at a depth of 800 yards, and not merely affected, but considerably cracked and broken. In all these cases one would like to see actual sections across the ground, and to ascertain where the break took place relatively to the workings. Mr. Barrow mentioned a most interesting case of a steeple, which reminded him of a letter which he had received from Mr. George Blake Walker. That gentleman recalled the case of an obelisk under which workings were carried. According to arrangement, the

Professor W. Galloway.

whole of the coal had to be taken out, and the colliery proprietors were to pay half the cost and the owners of the minerals the other half to restore the obelisk. The workings were carried through under the obelisk, and it was found to remain standing perfectly vertical, and no one was put to any expense. Mr. Treharne Rees referred to a case of workings in one seam affecting the workings in another seam 120 yards above it. That was quite in accordance with M. Fayol's theory; that was to say, as the dome extended outwards over the solid, it then, according to M. Fayol, returned backwards after a certain height had been attained. In considering these cases, it must be remembered that M. Fayol had made the following reservations in regard to his numerical conclusions:—"These figures have no pretence to absolute exactness, but they appear applicable to cases in which beds of sandstone constitute the principal part of the overlying strata, and the inclination does not exceed forty degrees." This would meet certain cases referred to in the discussion. As he had already stated, he hoped gentlemen who had the opportunity would let the Institute have some exact observations on the subject, and then they would have something to go on to challenge or to confirm M. Fayol's conclusions. But he ventured to think that nothing that had been elicited in the discussion, so far as it had gone, had any pretence to the same scientific accuracy as that which characterised the observations of M. Fayol.

The President.

The President said they were all very much indebted to Professor Galloway for his Paper, which had produced an excellent discussion. He had great pleasure in proposing that a vote of thanks be accorded to Professor Galloway for the trouble he had taken.

The discussion then closed.

DISCUSSION ON "THE COST OF SECONDARY HAULAGE."

The President

The PRESIDENT said that the next matter for discussion was Mr. W. J. Heppell's Paper on "The Cost of Secondary Horse Haulage."

Mr. E. M. Hann

Mr. E. M. HANN said that some time ago he took out particulars of the same kind as those treated in the Paper. He took them much in the same way as Mr. Heppell had done, but he did not include veterinary services and shoeing. In his case the cost of haulage was considerably greater in pulling up from the dip than down from the rise, although he had heard people maintain that they could haul coal as cheaply one way as the other. The question of gradient no doubt had a great deal to do with it, especially where there was such a gradient that a horse could not conveniently manage a single tram either from the rise or from the dip—one was almost as bad as the other. The question of distance from the face had the effect which Mr. Heppell described, and also which Mr. Galloway mentioned, namely, that the cost per ton per mile was lower in those cases where the distance hauled was greater. But this was not quite to the same extent as he had expected. With regard to fixing a distance which was the most economical, that, of course, was very difficult to do, but the saving effected by carrying the engine power close to the face was so much greater than the benefit of letting the haulier carry the tram a little further when he had got it hitched on to his horse, that he could not find any point at which there was not economy in getting the engines close up to the face. A distance of 130 or 140 yards produced the most economical results in the horse haulage—that was, cost per ton, not cost per mile. The chief factor in regulating the cost was a fairly obvious one, namely, as to whether a horse could bring one, two, or three trams. Wherever a horse was

Mr. E. M. Hann. able to work two trams, it was in every case superior to the results in those districts where a horse was only able to do one. As to results worked out per mile, he had no case lower than 11*d.*, and it went up to as much as 2*s.* 6*d.* per ton per mile, that was, haulage from the working place backwards, including every item of cost except those he had mentioned. What was called in the North train haulage was a very different matter. He well remembered that certain costs were got out which showed for train haulage, where the horse had favourable gradient, that it was done a little over 2*d.* per ton per mile. In that case the horses were able to take a load of about eight trams of 25 cwts. each, and the distance would be a quarter of a mile. The long distance mentioned by the writer—900 yards—bore this out. It seemed to work out the lowest cost per mile, but the actual cost per ton would be higher.

Other papers had been read on this subject, and it had been conclusively shown, he thought, that in spite of the advantage of the larger tram employed in South Wales, cheaper results accrued in the North with small ponies and small tubs. Of course the northern mines had many advantages over those in South Wales. There, better roads could be more easily maintained, the roofs were better, there were not so many obstructions on the roads, and it was a common experience for a haulier to go a considerable distance with his load without stopping, and those numerous stoppages, he considered, were largely responsible for the small number of tons of coal hauled per horse per day in South Wales. In a north country colliery the ponies jogged along at a higher speed and they had fewer stoppages.

Mr. Galloway mentioned instances of eight tons per horse per day being hauled, varying up to a maximum of 25 tons. He was inclined to think that both figures were rather extreme,

Mr. E. M. Hann.

that the average in South Wales would be, under ordinary conditions, from 14 to 16 tons per horse per day. He ought to mention that in taking out his figures he took into account the rubbish hauled per day, and he thought Mr. Heppell had done the same. He did not take into account night haulage and night rubbish, neither did he measure the distances the rubbish was taken. He had to take it the same distances as the coal; but that would not make any important difference.

Mr. W. D. Wight.

Mr. W. D. Wight said that in order that he might be able to compare some work he was doing with the statistics given by the writer, he had particulars taken out in a few districts under varying conditions. These were shown in the following table:—

	Tonnage	Mile Tons	Average Distance	Number of Horses	Days Worked	Cost per Ton Mile	Actual Cost
						s. d.	s. d.
A	1,795	747	733	14	84	0 9·0	0 3·7
B	1,890	814	758	19	114	0 11·3	0 4·8
C	1,442	343	418	4	48	1 0·5	0 3·0
D	1,046	314	528	7	84	1 10·4	0 6·7
E	1,351	230	300	—	30	1 8·5	0 3·5

He ought to say that the results given in lines A and B were in favourable districts where the gradient was with the load almost altogether. Large heavy trams were used, and although the horses were not taking more than one tram in any one case, yet they took a good load behind, because the trams averaged something like 33 cwt. to 35 cwt. Then, with a lighter tram in another colliery, also in rise workings, the figures were as shown in line C of the table. In the dip district, with the same light trams in the same colliery, the figures were given in line D. The conclusion he had come to with regard to horse haulage as against mechanical haulage was this: that with a fair light gradient, varying up to two inches on the

Mr. W. D. Wight. yard with the load, horses would successfully compete with machinery, and with economy, but that when they came to work dip coal, even a small dip, the advantage undoubtedly lay with machinery. The distance, too, as Mr. Hann had remarked, affected the question. If they had long distances, and were able to break up the horse haulage so that horses served from partings to partings, they reduced the cost very much. He believed that even with heavy rise workings machinery would beat horses. Now, he had taken another place which was worked entirely without horses, although he admitted it was not worked wholly with machinery, because the coal was hand-putted as far as the end of the stall from the face. But he had included the cost of this working by hand through the length of the stall, inasmuch as it would not be fair to leave it out in comparing with horse haulage, and in that case the secondary haulage worked out as shown in line E of the table. This included the engineman at the air compressor, and the consumption of coal in working that compressor. In the tonnage cost he had not taken rubbish into account at all. He had only taken the actual cost with the work done. He did not include the shoeing-smith work, but the cost of veterinary and farrier services were included. Thus the figures for comparative purposes might be useful. As he had said, given a favourable gradient, horse haulage would hold its own with mechanical haulage as far as secondary work went, on account of the greater convenience.

Mr. Hann. Mr. HANN said he forgot to ask the writer, with regard to the case of the 900 yds., whether all the horses that went to the face came right back the 900 yds., or whether it was worked by what was known as train horses.

Mr. W. J. Heppell. Mr. W. J. HEPPELL replied that some worked from the face to the double parting, and some from the double parting to the top of the incline, and that between the two inclines the horses took four trams at a time.

Mr. Hugh Bramwell.

Mr. Hugh Bramwell said that he had been prompted, like Mr. Hann, to compare the instances which Mr. Heppell and others had given with what was done in other parts of the country, and he looked up the contracts made for putting in the county of Durham. He found that an average rate for hand-putting there was 1*s.* 2½*d.* per score of ten tons for 80 yds., and 1½*d.* per score of ten tons for every 20 yds. in addition. At one or two collieries the average distance the putters worked was 140 yds., or 1*s.* 7*d.* per ten tons. Consequently, the cost for labour alone of this putting, taking these figures, was 1*s.* 11*d.* per ton per mile, so that he did not think South Wales had so much to complain about compared with the contract prices for putting in the county of Durham. In Cumberland a great deal of coal was worked by hand trailing, and there it was quite a common thing to pay 1*d.* per ton for 100 yds., or 1*s.* 5*d.* per ton per mile. For pony putting in the county of Durham the average rate was 1*s.* per score of ten tons for 130 yds., 1*d.* per score of ten tons for 30 yards extra. The average distance was 190 yds., or 1*s.* 2*d.* per ten tons, or 1*s.* 1*d.* per ton per mile for labour only.

Mr. H. T. Wales.

Mr. H. T. Wales said that he had commenced a comparison similar to those which had already been given, and he should be glad to furnish it at the next meeting. It was a case in which the whole of the haulage, so far, was done by horses.

Professor W. Galloway.

Professor W. Galloway said he should like to ask gentlemen who compared the cost of haulage, instead of taking a special district as Mr. Wight had done, to take the whole of the pit, because, as they all knew, some districts were much more favourable than others. In the paper which he read before the Federated Institution of Mining Engineers on the subject of secondary haulage, he made a comparison between the costs of various kinds of secondary haulage. Mr. Hann mentioned that ponies were cheaper than large

Professor W. Galloway. horses. That was obviously the case, as could be seen from a little table given on page 20 of his (Professor Galloway's) paper. He there gave the cost of pony putters at 1*s.* 4·879*d.* per ton per mile; hand putters, under very favourable circumstances, 1*s.* 2·740*d.*; and small engines, 1*s.* 1·056*d.*, and the small engines were given for the whole of the colliery, and not the most favourable districts. These were all the points to which he would now refer, and perhaps he might be allowed to take further part in the next discussion.

Mr. W. D. Wight. Mr. W. D. Wight said that in three of the five instances which he had given, the figures referred to the whole of the pit—small pits, he admitted.

The President. The President said that the subject under discussion was of so important a character that he proposed it should be further considered at the next meeting. He had noticed that the writer of the Paper made the cost of horse-keep at something less than a shilling per horse per day. There were 92 horses, costing £1,625 for 365 days. That was a little less than a shilling. In a similar Paper, read by Mr. Green before the Rhondda Colliery Officials' Association, the cost worked out at 1*s.* 2*d.* He had looked into the matter, and he found that the cost came out about 1*s.* 4*d.* simply for food alone. This was a difference which would affect the figures given in the table of cost in the Paper. He was of the same opinion as Mr. Hann, that where they had long horse haulage it must tend to reduce the cost per ton per mile; where the haulage was short the numerous changes at the face of the workings, of course, took time and added to the cost. The longer haulage was as a rule on the better part of the road, and the horse did not stop, and generally took a larger number of trams. With regard to horse *versus* mechanical haulage, he was strongly of opinion that to work a colliery economically they must have both. There were some cases in which it would be simply ruinous to attempt to do the haulage by horses only, and in other cases it would be most unwise and uneconomical to put up engines where horse haulage was really cheaper than any mechanical arrangement. He had no doubt that at the next meeting several members would be desirous of adding to the discussion of this interesting Paper. The President.

The discussion was adjourned.

Mr. Edwin Cottam then read a Paper on "Coal-getting without Blasting" (p. 378), and exhibited the apparatus to which he specially referred.

A Paper by Mr. Hort. Huxham on "Some Local Disturbances in Anthracite Collieries" was taken as read and ordered to be printed in the Proceedings (see p. 384).

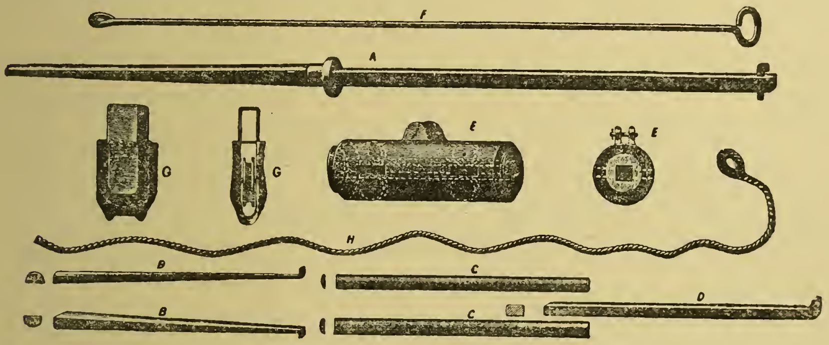
A vote of thanks to the President closed the proceedings.

COAL-GETTING WITHOUT BLASTING.

By Mr. Edwin Cottam.

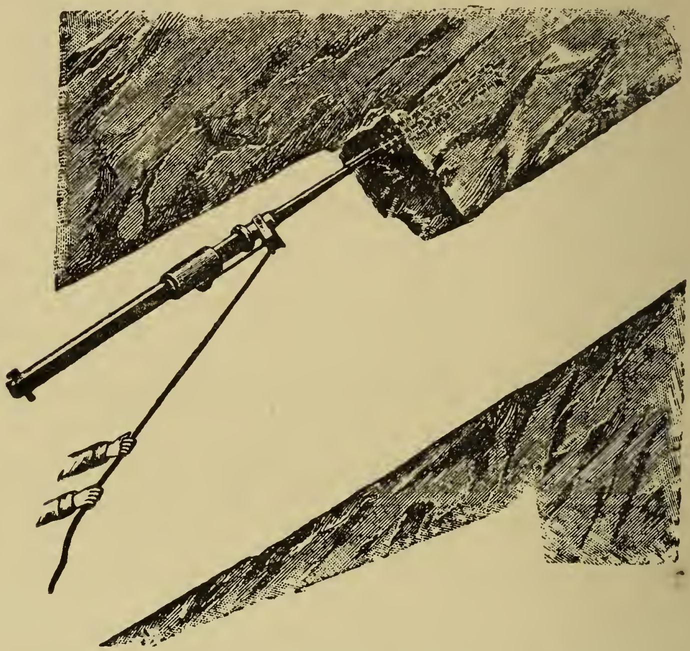
In September 1896 the writer made a tour through Belgium, Germany, Bavaria, and Austria-Hungary, as far as Buda Pesth. The object of his visit was to see the principal works and manufactories *en route*, chiefly engineering and carriage and wagon works, and also to inspect the exhibitions then being held at Nuremberg and at Buda Pesth. Amongst other things that came under his notice during his travels, was a machine for coal-getting, which he calls the Tup Wedge, and with which he was especially struck, in view of the provisions of the Bill which was then passing through Parliament bearing upon the use of explosives in mines. The working of the machine was explained by Mr. Thomas, the patentee, and the writer thought it might be a matter of interest to bring before the Institute. He ordered a machine to be sent to his works at Cardiff, and Mr. Thomas very kindly undertook that one of his representatives should come over for the purpose of being present at the experiments.

The Tup Wedge is intended for wedging down coal, shale, or soft stratified rock. The following is a description of its construction and method of working:—A hole is drilled in the coal in the usual way, as if intended for a charge of explosives. The half-round feathers, or wedge pieces B B, are then inserted on opposite sides of the hole, with the half-round section next the side of the hole, and the flat part towards its centre; the guide pieces C C are then inserted on opposite sides of the hole, between the wedge pieces B B, so as to form a rectangular opening for the insertion of the driving wedge A, and keep it parallel in the hole. The rectangular driving wedge A is then inserted between the wedge pieces B B, and driven home tight. The "tup," or cylindrical iron weight E, which has a square hole through its centre, so as to fit loosely on the shank or outer square end of the driving wedge A, and is provided with four small rollers to reduce the friction when travelling thereon, is then placed in its position upon A, and the iron rod F is attached to it at one end, by a pin passing through two small snugs on the outside of the tup E. Taking hold of the handle at the other end of F, the collier can then readily work the tup backwards and forwards on the shank A, allowing the tup to forcibly strike against the fixed collar at the outer end of the driving wedge A, and by repeated blows the wedge A is thus forced in between the wedge pieces B B, separating them, and causing the coal to break off.



When the wedge A has been driven in for its full length without producing a fall of the coal, as is sometimes the case, the wedge A is withdrawn, to allow of the insertion of a rectangular distance piece or liner D, after which the driving wedge A is again inserted, and driven in until the coal falls.

When the hole is a good deal inclined upwards, it has been found advantageous to substitute for the rod F a strong cord, running through a small sheave or pulley G, which can be readily fixed on A, on the inner side of the striking collar, as shown in the accompanying diagram.



WEDGE WORKING NEAR ROOF, INCLINED UPWARDS.

The apparatus entirely obviates the use of powder in the dangerous parts of mines, and its results of working are quite as economical as blasting, while the percentage of large coal is considerably increased in both soft and hard seams.

At one of the meetings of this Institute the writer met Mr. William Smith, manager of the Rhymney Coal Company, who agreed to give the Tup Wedge a practical trial. Mr. Mensing, the representative of the patentee, was present at this trial, and Mr. Mensing's report is as follows:—

The results at the Rhymney Iron and Coal Company were exceptionally good. I worked several times in coal, and got such a lot of coal down, that the mining engineers and the miners were really astonished. The quality and hardness of the coal were very favourable for the work of the Tup Wedge.

The seam is about 5 to 6 feet, very hard coal. We got down only big lumps of coal; no dust. Each operation took about five minutes' work. Once we brought down about three wagon loads; another time about six wagon loads (I reckon wagons of the size used in Belgian coal mines). The managers and the engineers were very pleased to see our machines, and complimented me about the results.

The author also asked Mr. Smith to kindly furnish him with his observations upon the experimental trials, and this is what he says:—

Rhymney Iron Works, Rhymney:
September 13, 1897.

Dear Sir,—I now have pleasure in giving you below extracts from the report made by our Mr. Powell as to the results of the trials made with your patent Tup Wedge at these Collieries in January last, viz.:—

No. 1 trial was made in a face of long work on the Upper 4-Feet Seam. The coal, which was 3 ft. in thickness, was hard and difficult to get without blasting. The hole was bored in the coal to a depth of 2 ft. 9 in., and the long wedge was then inserted, and the machine set to work. It took two men to work it, as the hole was slightly inclined towards the roof. After working the machine for about 10 minutes a large piece of coal, about 2 tons, was brought down, very little small coal being made in the process. The piece of coal was in a position most favourable for bringing down, as it was overhanging, and no holing was required.

No. 2 trial was made in a similar face of long wall, about 50 yds. from where the first trial was made, and in this case the hole was bored to a depth of 3 ft., and the machine was worked by one man only for a short time; but the work being too heavy another man was put on to assist him, and after working the machine for about 7 minutes they succeeded in getting down about 30 cwts. of coal. This again was a piece of overhanging coal, and which was very much in favour of the machine.

No. 3 trial was made in the roof, the nature of which is hard clift, and the thickness taken down on the roadways is about 20 in. by 6 ft. wide. In this case the hole was bored about 3 ft. in depth, and the large wedge was inserted, and the apparatus set to work. Two men worked it for about 15 minutes, and the ground then began to open. Then a second wedge was put in by the side of the large one, and after working the machine for about an hour the roof was brought down in one large stone, but the sides did not crop as well as when explosives are used. The roof is generally brought down by blasting, and very little labour is then required in br
up the stones in suitable sizes for stowing in the gob, but with th
Wedge a considerable amount of labour was required in breaking u

stones sufficiently small to stow away. With this process of getting the roof down it is much more costly than when explosives are used, and we estimate that this labour in connection with the machine would be about 30 per cent. more as against the use of explosives. Very little small coal is made by the use of the Tup Wedge, and the quantity of large produced would compare favourably where explosives are used.

With bad roofs, and the consequent use of posts, and where the distance between the gob and the face is only a few feet, the machine could not be very well used, owing to the length of the wedge; but this, I have no doubt, could be overcome by using a shorter wedge. The weight of the apparatus is also against its being generally adopted, as the combined weight of the apparatus, the boring machine and the wedges, is too heavy to be carried about, and during the trials here the apparatus had to be taken from place to place by horse and tram, and that, of course, adds to the cost. We are of opinion that this machine will not supersede the use of explosives in our mines.

We were very favourably impressed with the Thomas Patent Drilling Machine. It is very strongly made, easily worked, and quickly withdrawn, and from the trials made in the roof and coal, the machine gave excellent results. The letter from Mr. Francois is returned herewith.

Yours faithfully,
William Smith.

Edwin Cottam, Esq.,
Bute Steel and Spring Works, Cardiff.

In a letter, dated July 3, 1897, to the author of this paper, the patentee says:—

It is the plain truth to say that the Tup Wedge is the most efficient and most economical way of working in mines where powder is prohibited. This has been proved. The Tup Wedge is of recent introduction. It was put on the market during the Spring of 1896. So far the sales have been as follows:—In Belgium, about 550; in Germany, about 100; in France, about 100; in Russia, about 50. . . . As regards the work done by the use of the Tup Wedge, the following figures may be of interest. They were published in the official Review of the Belgium mines, at Liege:—

ADVANCEMENT MADE IN CUTTING OF GALLERIES IN HARD ROCK.

(Per Shift of Ten Hours.)

	Metres.	Percentage.
With Powder	1·23	100 per cent.
„ Pick	0·30	24·3 „
„ Common Wedge	0·50	40·7 „
„ Patent Wedge	0·75	61 „
„ Patent Wedge Driver	0·90	72·5 „
„ Tup Wedge	1·00	81·3 „

The mining engineer who arrived at these figures concludes in this way:—"The Tup Wedge will easily do four-fifths (80%) of the work done by powder. The cost of working by Tup Wedge is about 20% above that of working by powder."

Now we may add that the nature of the rock has a great influence upon the results obtainable with the Tup Wedge. We have had instances where the Tup Wedge has actually done more work than powder. Also, with practice, the men get more effect with the Tup Wedge, and come very close to powder work.

In compiling this Paper, the writer wishes it to be clearly understood that he makes no pretension to expert knowledge of methods of coal-cutting; his object is to put members of the Institute in possession of information concerning a machine which, he thinks, can be used in the coal mines of South Wales, as a substitute for blasting, with accruing advantage to the workman in regard to safety, and to directors and shareholders in doing something to minimise the risk of colliery disaster, with its attendant great monetary loss to the owning Company.

SOME LOCAL DISTURBANCES IN ANTHRACITE COLLIERIES.

By Mr. Hort. Huxham, M.Inst.C.E.

In many of the anthracite collieries of South Wales, the disturbances met with more generally took the form of a folding of the strata and dislocation resulting from side pressure, rather than slip-faults, or vertical dislocation; and, in consequence, considerable difficulty was frequently experienced in laying out the colliery workings on any preconceived plan, and it became necessary to adjust the drivages from time to time, to meet the recurring changes of dip and the physical conditions met with as the work proceeded.

The anticlinal and synclinal curves, produced by the folding of the strata from side pressure, although bearing a very general resemblance one to another, were very variable and unstable in character, and any one fold might vary within very short distances from a very slight undulation, in one part of its course, to a sharp curve bending up the strata suddenly to a height of many yards above its normal position, in another part of its course, and then as rapidly die away again or disappear altogether a little further on.

At times, again, although comparatively unfrequently, an anticlinal fold may in some part of its course change into an overlap fault, resulting from the resistance of the ground to the enormous pressure of the side thrust having caused one portion of the strata to be forced over the other, instead of having been simply folded into an anticlinal ridge.

Minor instances of small overlap faults, with a horizontal dislocation of a few feet, were frequently met with in the course of working, quite irrespective of the vicinity of any anticlinal disturbance. In almost every case the seam of coal ran out in a wedge-shape form into the roof or floor, as the case might be; and immediately below or above, or possibly separated by a small thickness of clod, would be found the other part of the seam, with its wedge-shaped end pointing in the opposite direction. Where this occurs, one part of the seam of coal is generally found forced over the other, so that for a short distance the thickness of the seam is practically doubled. In almost all those cases of small overlap faults, the angle of the break varied from 15 to 25 degrees from the horizontal.

Those overlap faults were locally called "changes of leaf," whilst the anticlinal folds were termed "rolls."

It is a curious fact that in most of the anthracite seams, the rolls did not, as a rule, affect the thickness of the seam or the hardness or quality of the coal, some of the hardest and best coal being found on the inclined sides of the rolls. If the folding has been very severe, a few yards of coal on the immediate crest or in the bottom of the trough (more generally the latter) may be found somewhat broken; but in no case does the writer remember having seen any really soft coal caused by those disturbances.

Generally speaking, the anticlinal lines ran in a more or less north-easterly and south-westerly direction. In the immediate vicinity and influence of the roll, the "slips" in the coal were generally found lying in a direction parallel with the axis of the roll, usually varying many degrees from the normal direction of the slips in the undisturbed portions of the seam, so that a variation in the direction of the slips in the coal was often an early indication of the working approaching a roll. Usually also, in the steep part of the roll, the slips were entirely absent, this extending sometimes for some distance on either side.

In most cases, the roof and floor of the seam retained its normal condition over the rolls, except occasionally it was found a little broken at the immediate crest, or in the bottom of the trough, more often in the latter.

In dealing with these disturbances it should always be borne in mind that, in addition to the local alterations in the dip brought about by the folding of the strata, the anticlinal ridges and the synclinal troughs, as a rule, themselves dipped in the direction of their axis, forming the least angle with the normal dip of the locality; so that, if the normal dip of any area be to the south, a folding of the strata running across such area in a south-westerly and north-easterly direction, would produce a south-westerly dip in the ridges and troughs of the folded strata.

It might be of some interest to the members if the writer gave some instances of this class of disturbances which had come within his own personal experience, in illustration of the difficulties which had at times to be contended with.

The chief workable seams in the district he was about to allude to, were as follows:—

	yds.	ft.	in.		ft.	in.
"Penycraig" or "Little Vein" coal . .					2	10
Ground, about	33	0	0			
"Big Vein" coal					5	6
Ground, about	45	0	0			
"Brass" or "Peacock Vein" . . .		3	6	to	4	0

On the Twrch Branch of the Midland Railway, a little to the south of the Gwys Station, there is a very fine section of a large anticlinal fold, or roll, exposed in the bank on the east side of the railway, as shown in the Section M N O (Plate 10); and immediately to the north of this the old Palleg Pit was sunk a depth of 30 yards to the Big Vein, which, at N, was exposed high above the top of the pit, and where the accompanying mine and beds of rock and shale were seen folded over, one after the other, in regular succession.

The workings in the Big Vein at Palleg touched the roll in several places, and its direction from that data appeared to be as shown at N, on plan No. 1 (Plate 11).

A cross-measure drift was driven northwards from the Big Vein, and intersected the underlying Brass Vein at P (Plate 10).

On the opposite side of the Twrch Valley, which at this point is very narrow, the Big Vein had been worked by levels in old times, and it was said that the ground was much disturbed, and that there were two or three separate layers or "leaves" of Big Vein coal worked for short distances.

Whilst the Palleg Colliery was working the Big Vein, and before the cross-measure had been driven to prove the Brass Vein, a pit was sunk on the Brynmorgan property at K, plan No. 1 (Plate 11), commencing on the hill side, about ten yards in vertical height above the top of the Palleg Pit. The old work in the Big Vein was passed through, and at a depth of 60 yards the Black Vein (a rider lying above the Brass Vein) was met with, and after sinking a few yards further the pit was stopped, as the owners thought they were in faulty ground.

A cross-measure drift was then driven to the north, from the level of the Black Vein, and the Brass Vein was intersected at L, and the coal found to be in a healthy condition, dipping some 4 inches on the yard towards the south.

Simultaneously with the sinking of the pit, a dipping cross-measure drift was driven from the surface, through the Big Vein down to the Brass Vein, to form a return airway, and as soon as a connection had been made with the level driven from L, coal-working (by long work) was proceeded with to the west and north. The coal was found to be in excellent condition, dipping to the south.

Some time after this, and when the first level was approaching the boundary, a cross-measure drift, dipping 1 in 3, was driven to intersect the seam at E, and it was at this time that the writer became connected with the colliery.

As the direction from E to R gave a dip of 2 inches per yard, and would run through the centre of the property, it was decided to drive the engine drift in that direction, and at the same time drive a dip heading to the south-west from E.

When the point R was reached, the first difficulty arose, for a change of dip occurred, and the direction E R became nearly level course, so that the engine drift was turned in the direction R S, dipping $2\frac{1}{2}$ inches per yard, and a branch road dipping $1\frac{1}{2}$ inches per yard was shortly after turned away to the west, and ultimately continued fairly straight up to the boundary. From this branch road, to the north-west, the coal was found under normal conditions.

On the engine drift arriving at S, a shallow synclinal was met with, as shown by the dotted line on the plan, and from thence to T, where the summit of the anticlinal was reached, the road rose some 2 inches on the yard, but after that the seam continued to dip in a southerly direction.

The dip heading, commenced at E, continued dipping 6 inches on the yard, to the bend shown on the plan, where a sharp synclinal was met with running in the direction of D to the east, but died away in a short distance to the west. The road then rose some $3\frac{1}{2}$ inches on the yard for the next 2 chains, where it reached the crown of the anticlinal, and was driven level from thence to C.

Whilst driving the engine drift from R to S, stall roads were turned away to the right and left, and the coal all worked off by long wall. The first three roads on the left hand, towards the south-east, holed into the dip heading driven from E, whilst the remaining seven roads were continued up to a roll (C), which folded the coal up south for 6 yards. Two exploration roads were carried over and through this roll, and in about 40 yards came up against another roll at B, folding the coal up south.

In driving the engine drift from S to T, there was no indication of either of the rolls C or B, other than T was found to be the summit or crest of a slight anticlinal.

The stall roads and branches driven eastwards from T, towards W, B, and A, continued in excellent coal. At W, these workings extended northwards for some 18 yards over the previous workings (dotted) from the engine drift, and all the way from W to B the coal suddenly dipped down vertically to the north. When arriving at B a pit was sunk 20 yards vertically in the coal and holed into the previous exploration workings from C, proving that the roll at that point folded the coal up to the south for 20 yards.

In continuing the belt of workings between A and B further to the east, the dip was found to turn round more to the east of south, and as a little water had been met with at A the faces were stopped, as there was no available pumping appliance, and the boundary was not far distant.

A roll or fault had accompanied the lowest road in these workings on its south side for the greater part of its distance. A fault had also been met with (as shown at V) in the branch engine road driven from T to V.

As the coal at B had been brought up very nearly to the level of the bottom of the pit at K, it was determined to drive a cross-measure heading to the south from K, so as to shorten the distance and provide engine-power for exploring and working the coal to the deep of A.

On reaching I, a fault was met with, and, very curiously, on breaking through the same a very fine section of Brass Vein coal was met with, dipping about 4 in. on the yard to the east, level course coinciding with the direction of the heading.

This was naturally a great surprise, as it was known that from K to I the Brass Vein was from 50 to 90 ft. below the heading, and there had been no indication in the previous workings underneath of any break, or upthrow fault, or disturbance, other than the rolls previously mentioned; and the roof and floor of the seam had retained its normal character throughout.

The heading was continued on in the coal for some two chains, where the bottom of the roll H was met with, and the coal was found to rise sharply in front of the heading.

Air-pipes had been provided for temporarily ventilating the heading whilst being driven from K, until a connection should be established with the workings A, B; but as the coal, so unexpectedly met with, gave off some gas, it became necessary to provide more efficient ventilation before the work could proceed any further, and accordingly a cross-measure was driven from the top of the roll, a little distance east of B, and a shallow pit sunk down from the coal to meet it. In driving this cross-measure, the ground above the coal near the roll was found quite regular for some 20 yards, when for the next 15 yards ground of a very mixed and disturbed character was met with, whilst the latter portion of the heading and the pit was in the regular ground usually found underlying the Brass Vein.

As soon as efficient ventilation was established, the driving of the heading K I H to the south was resumed and the working of the coal proceeded with. The heading met two rolls at H and G, and was stopped in the latter.

In prosecuting the working of the coal it was found that the roll H turned round towards C, so that the dip of the coal, instead of continuing in an easterly direction, became a few degrees west of south, corresponding almost exactly with the dip in the lower workings at A.

The area of this coal was found to be limited towards the north by a line of fault, against which the coal ran out. A little water was met with, and the coal could not be worked below the lowest road without providing means for dealing with the water. The roof and floor over the whole of this area was in its normal condition, and some 10,500 tons of coal were obtained.

On referring to the slip attached to Plan No. 1 (Plate 11), and the sections G, H, I, K, L, and A, B, C, D, E, F (Plate 10), it would be seen that the coal extended for a distance of some 100 yards to the west, over the previous workings at B, and that no indication of the 20-yard roll, which was met with at B, was found in the upper coal.

Another curious feature was, that in none of the workings between A F and G L could the large roll found at N, at the Palleg Colliery, be traced.

The writer has no doubt that the appearance of the upper bed of Brass Vein coal in the position in which it was found was due to an overlap fault, but he is not at all clear as to its precise direction, or in what manner it was brought about; and, as a study of disturbed ground, he regretted having had to stop the heading K G.

Another example of the same class of disturbance was met with at the old Cwmllynfell Colliery, about a mile distant to the north-west, and which was under the writer's charge for many years.

On reference to Plan No. 2, and Section (Plate 12), it would be seen that the level courses in the Brass Vein Coal were extremely irregular, due to a considerable folding of the strata.

The pit, about 120 yards in depth, happened to be sunk on a sharp but small synclinal. An engine drift was driven towards the south to avoid this, and levels turned away therefrom as shown on the plan. The course of those levels indicated the contour of the strata, and showed the variable and unstable character of the folds.

The synclinal F died out to the south, before reaching the west level driven from B, and became also very much less severe towards the north. The anticlinal G widened and ran out to the south, whilst a few chains further north it was very severe, but died away again before reaching the west level from the bottom of the pit.

The synclinal H, which was of large dimensions, nearly died away in the south workings at B, and also decreased very much to the north at the pit.

The anticlinal C was of very large dimensions, and could be traced for over a mile running in a north-easterly and south-westerly direction. A very fine section of it (in the Black Vein mine and strata above the Penycraig, or Little Vein) was exposed in the cutting on the west side of the railway, a short distance north of Handraforgan Colliery, and from thence it could be seen crossing the river towards the north-east. Near the pit the crest of this roll was wide and flat, and when the engine drift met the steep inclination on its east side, it was continued at somewhat less than half course down the inclination, until the bottom of the roll was reached, when the drift was turned parallel with its course.

Upon the engine drift reaching D, a cross-measure heading (D B) was driven to cut through the roll and intersect the coal on the west side, and at the same time an airway was driven in the coal over the roll, as shown in the plan and section. The cross-measure intersected the Trigloin Vein, lying below the Brass Vein, but the coal proved too thin for profitable working, although its quality was very good.

The whole of the coal over these foldings of the strata maintained its full thickness, and was of excellent hard quality, and the roof and floor retained its normal character. In no part of the work was any soft coal met with. There were no slips inthe coal in the steep part on the eastern side of the roll C.

In these disturbed areas the writer had found great advantage in working the coal from the rise towards the deep instead of *vice versa*; as usually no water was met with, the gas drained off much more readily, and, as a rule, the engine power was more readily at command for haulage and dealing with some of the sudden changes of the dip of the strata.

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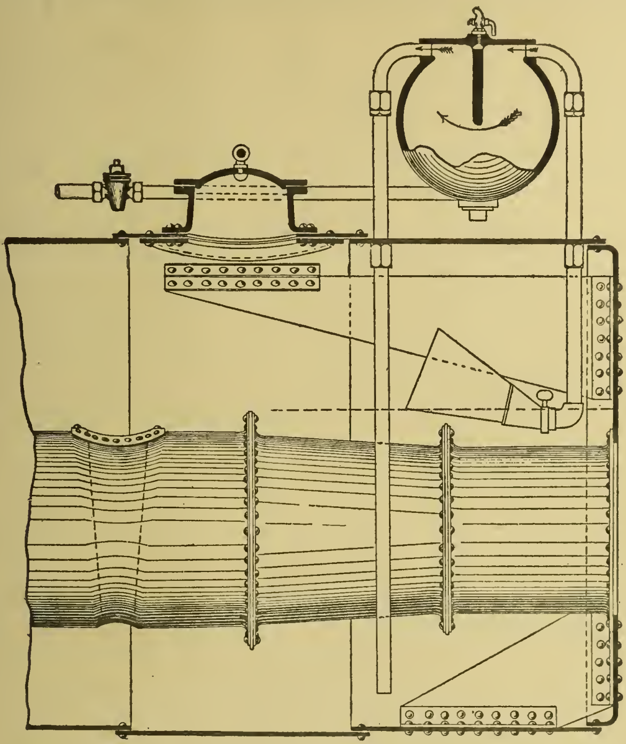

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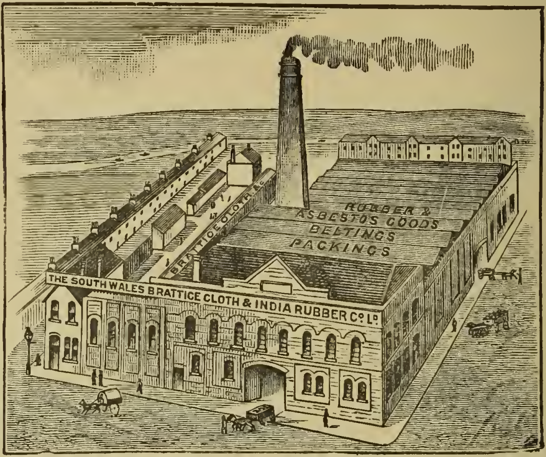
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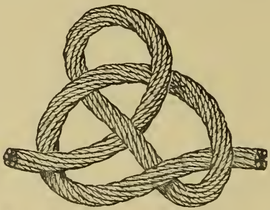

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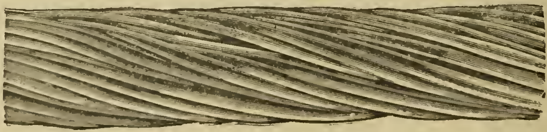

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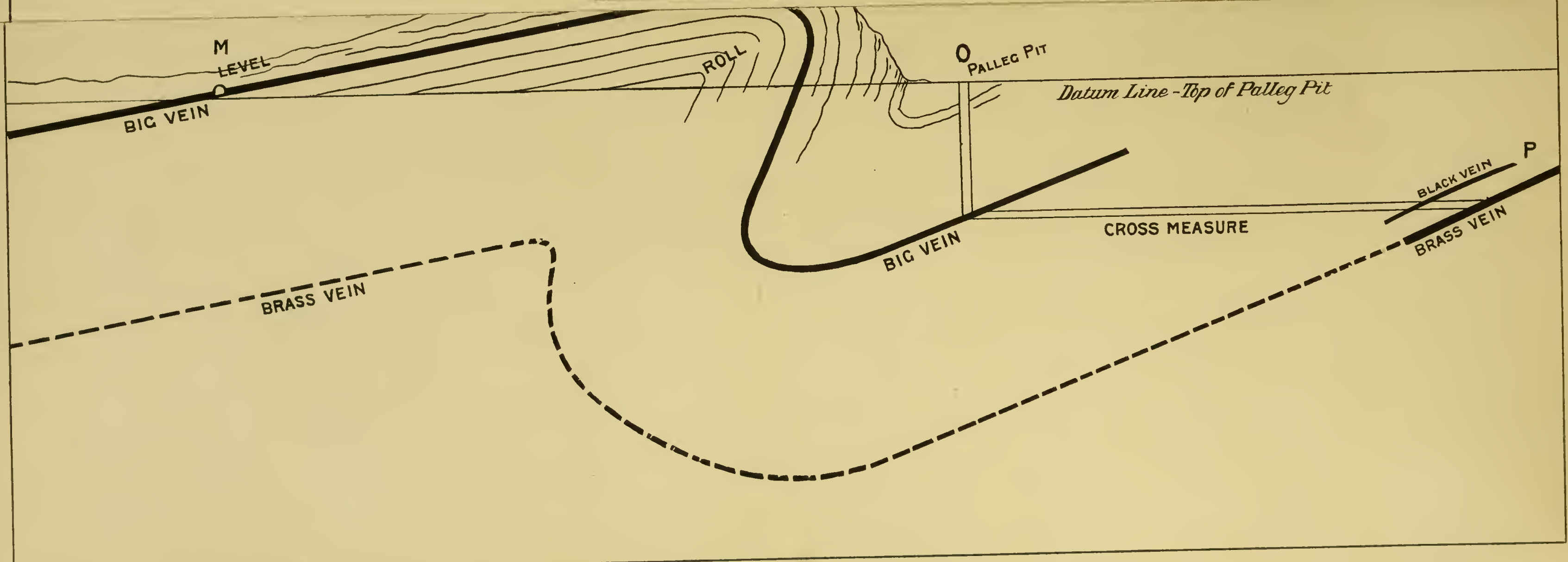

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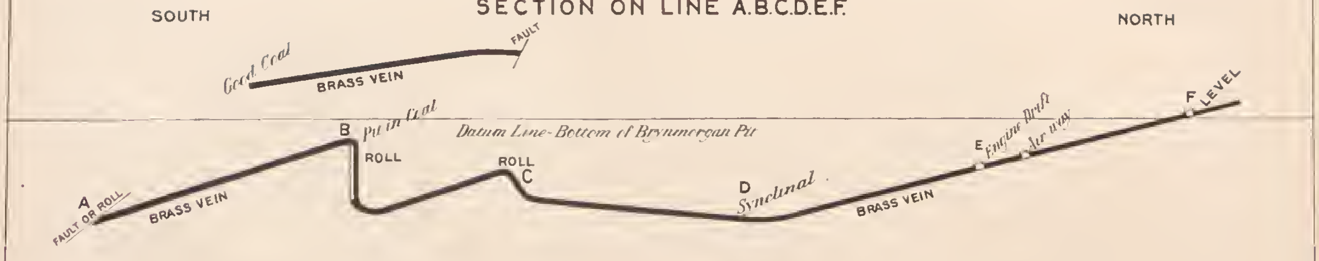

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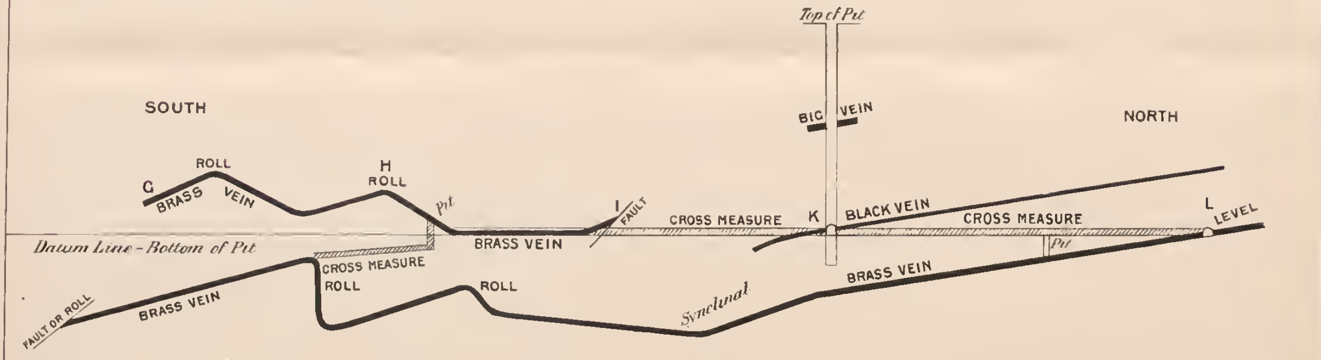

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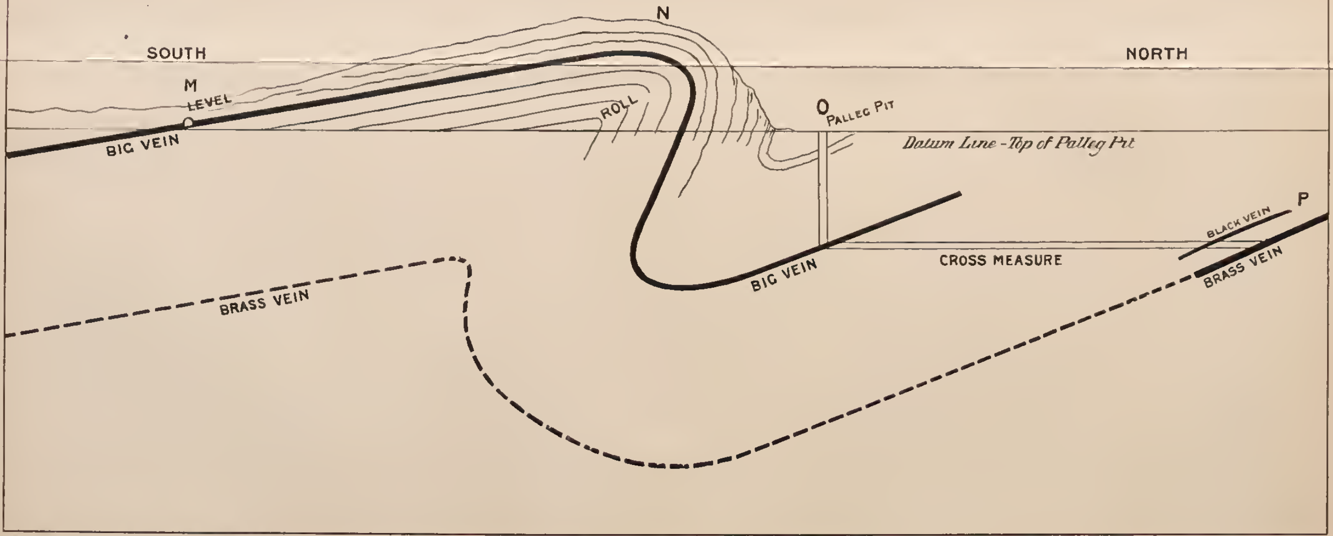

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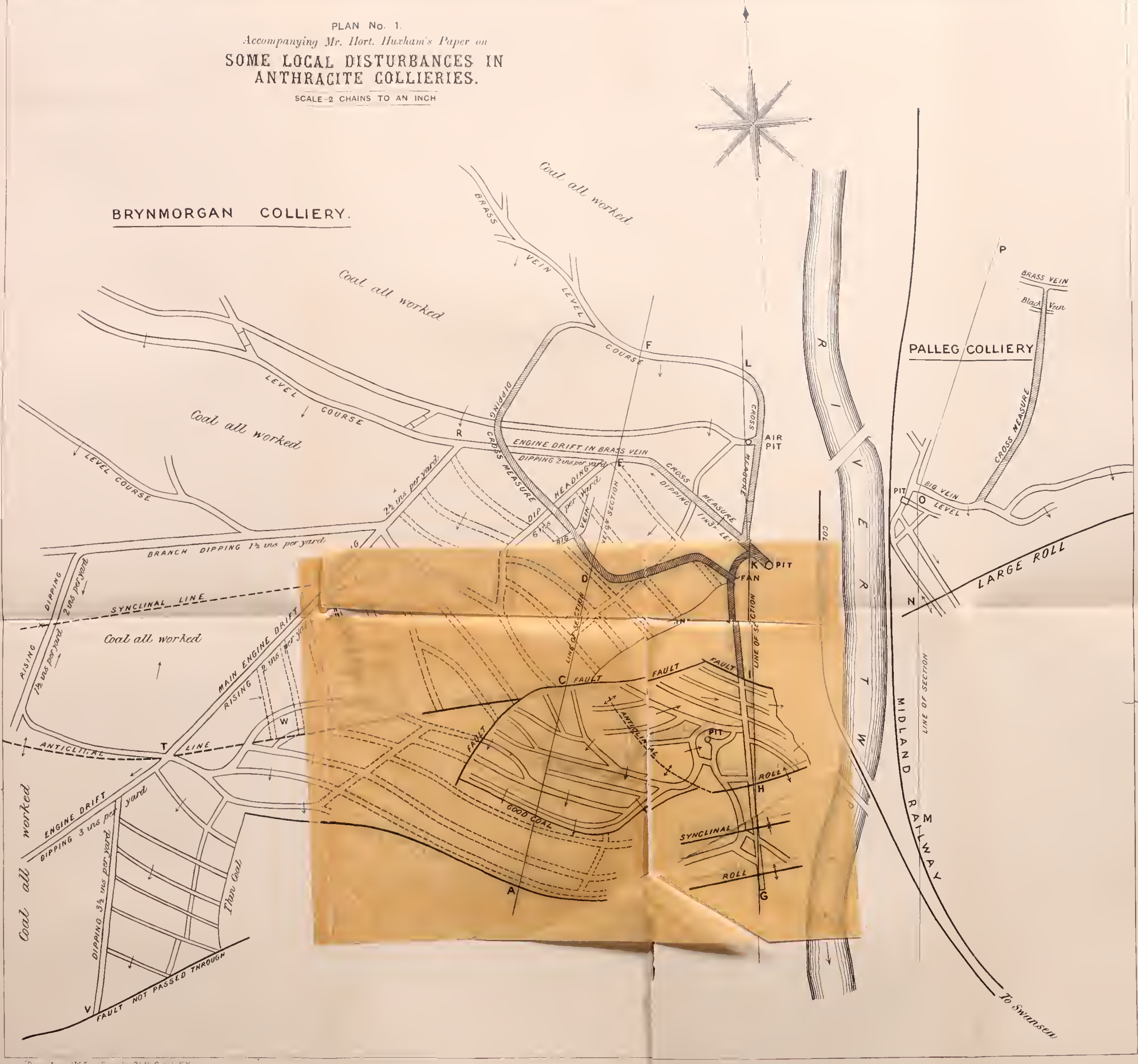

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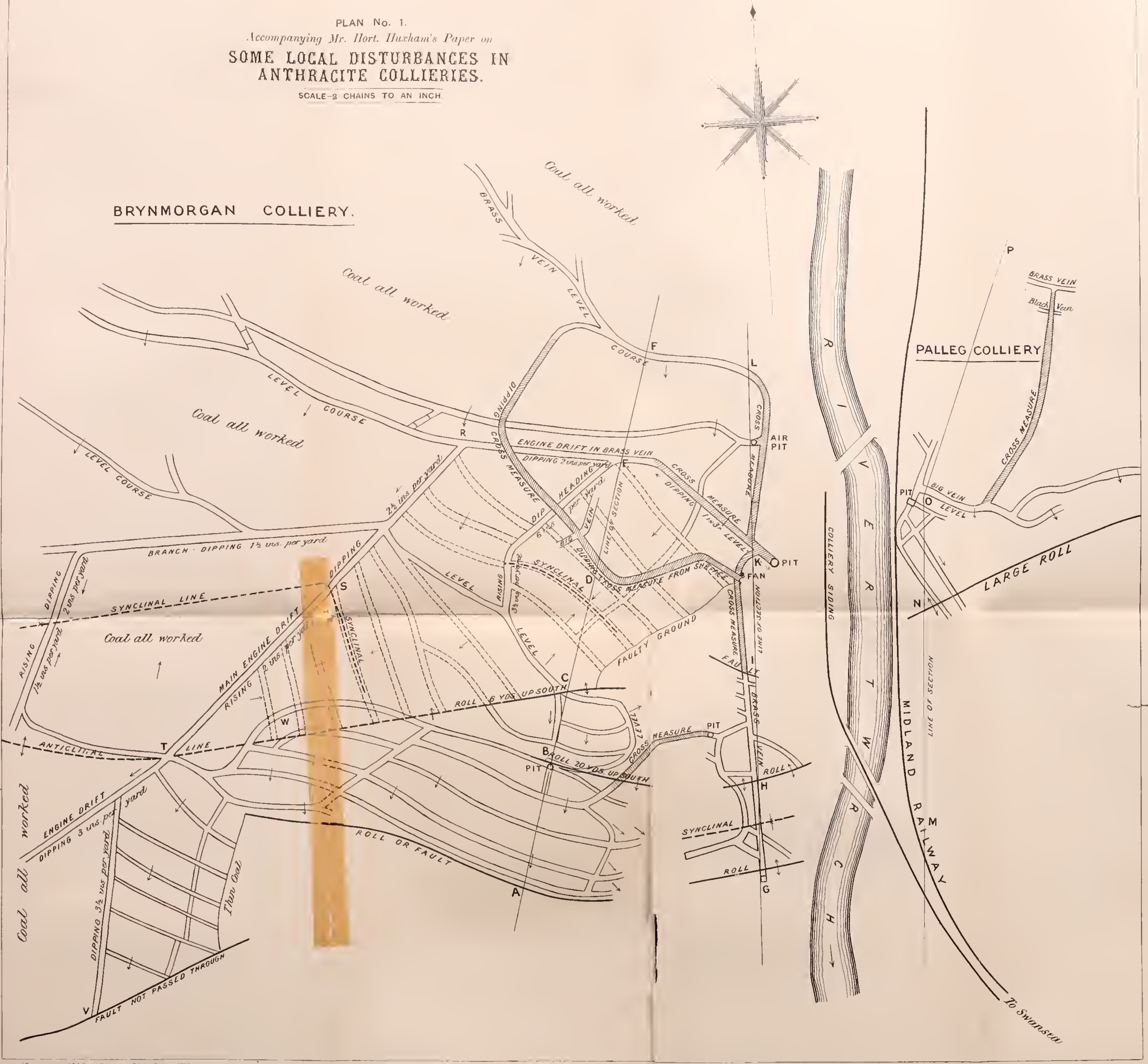

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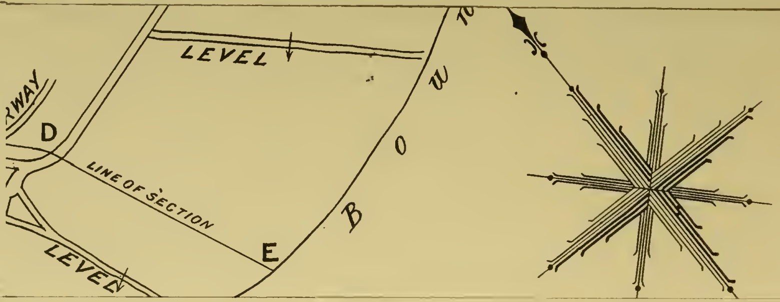

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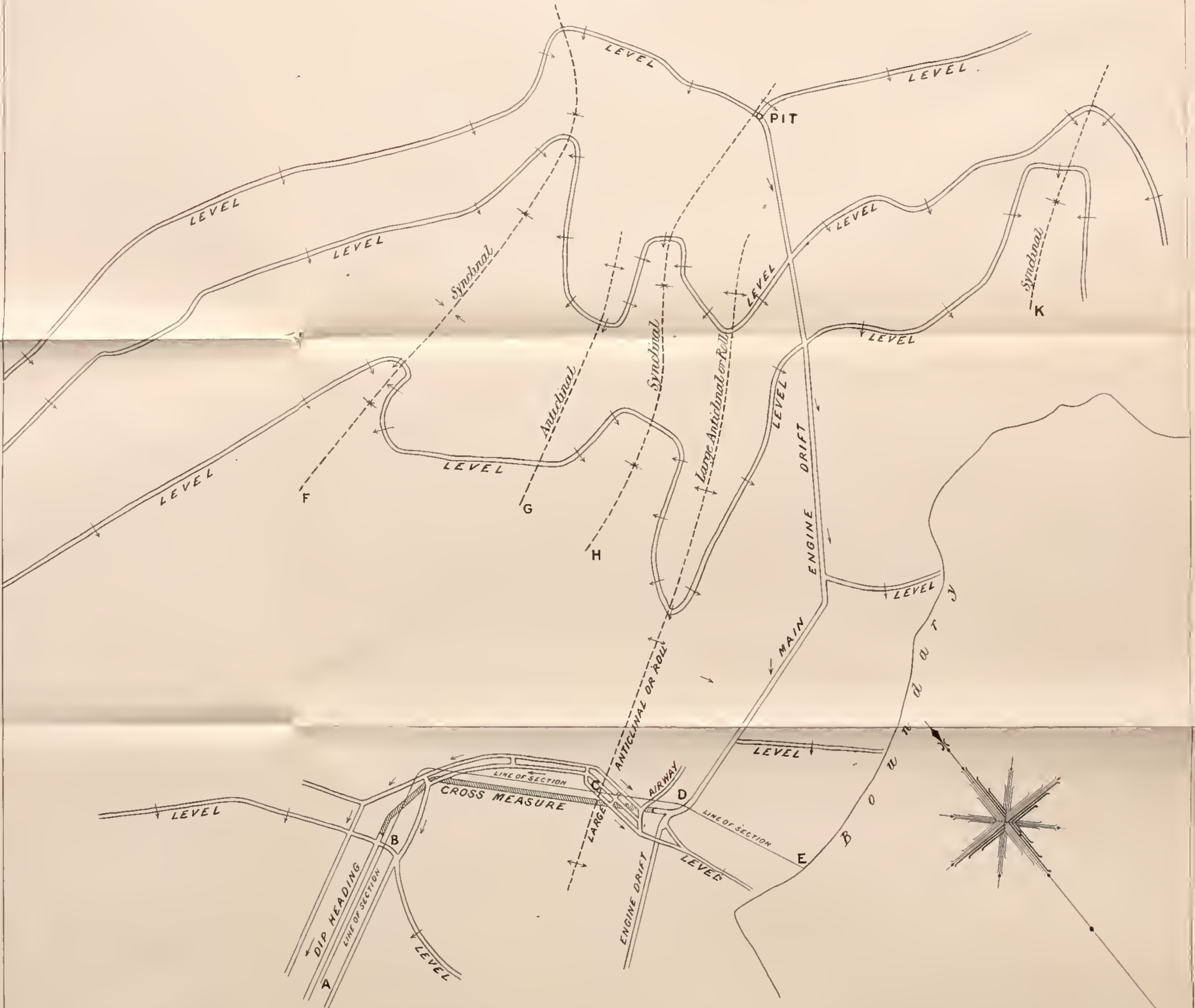

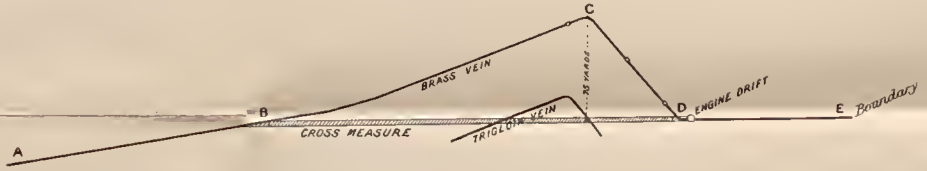

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